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The Sauropod Dinosaur Barosaurus Marsh

Redescription of the Type Specimens in the Peabody Museum
Yale University

BY

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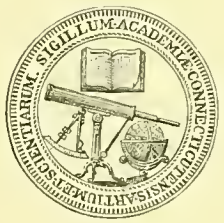

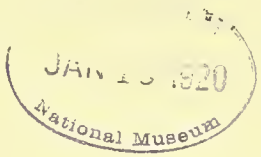

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PREFACE

The preparation of a monograph on the sauropod dinosaurs, which was one of the many planned by Professor O. C. Marsh, is now being carried forward by Professor H. F. Osborn. At the latter's request, the great type specimen of *Barosaurus* Marsh in the Yale Museum has been fully prepared for study, in order that an adequate description of this important genus might be embodied in the monograph. This was done during the winter of 1917, and proved to be a very heavy task even for three preparators, but the specimen as thus revealed fully compensates for the labor, since, except for the fragmentary character of the limbs, it proves to be one of the finest dinosaur skeletons in the possession of the Museum. The study of the material was made while the collection was still in the old Peabody Museum building. The vertebræ were of necessity boxed for removal and storage, and have since been utterly inaccessible for further reference, hence it has been impossible either to verify or add to the measurements on the original bones. If errors have crept into the description, they may be in part attributed to this; but it has not been deemed wise to delay publication, perhaps for several more years, until the new building is completed and the collection installed therein.

In the preparation of the memoir I have received very material aid from Mr. O. A. Peterson of the Carnegie Museum, Pittsburgh, who supplied measurements from the type of *Diplodocus carnegiei,* the mounted skeleton of which is there displayed. By the American Museum of Natural History, New York City, I was permitted to study and measure the exhibited partial skeleton of *D. longus* described in 1899 by Professor Osborn. To Miss LeVene, the executive secretary of the Peabody Museum, I am deeply indebted for the preparation of the manuscript and for part of the literary research.

INTRODUCTION

Original Descriptions

Professor Marsh's original description of *Barosaurus* was published in the American Journal of Science for January, 1890, pp. 85-86, Figs. 1 and 2, and reads as follows:

Barosaurus lentus, gen. et sp. nov.

A new genus of the Sauropoda is indicated by various remains of a very large reptile secured by the writer during the past season. The most characteristic portions examined are the caudal vertebræ, which in general form resemble those of *Diplodocus*. They are concave below, as in the caudals of that genus, but the sides of the centra are also deeply excavated.

In the anterior caudals, this excavation extends nearly or quite through the centra, a thin septum usually remaining. In the median caudals, a deep cavity on each side exists, as shown in Figs. 1 and 2 [Fig. 1, A, B] on page 86.

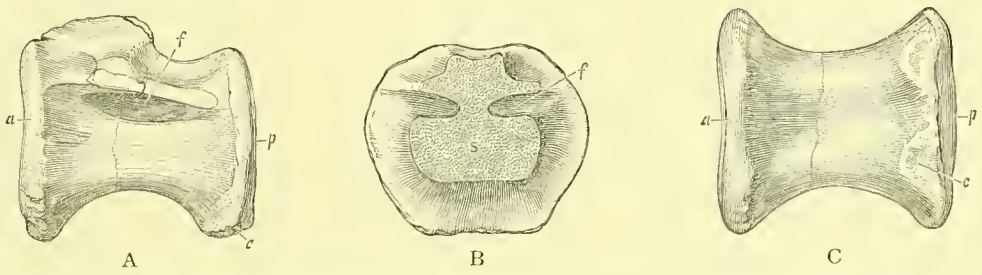


FIGURE 1.—A, Caudal vertebra of *Barosaurus lentus*, after Marsh. Median vertical section. B, Left lateral aspect of the same bone. C, Ventral aspect. All one-eighth natural size.

On the distal caudals, the lateral cavity has nearly or quite disappeared. All the caudal vertebræ are proportionately shorter than in *Diplodocus*, and their chevrons have no anterior projection, as in that genus.

The remains on which the present description is based are from the Atlantosaurus beds of Dakota, about two hundred miles further north than this well-marked horizon has hitherto been recognized.

A supplementary description by Professor Marsh is found in his *Dinosaurs of North America*, 1896, pp. 174-175, Figs. 24-26:

Barosaurus

Another genus of the Sauropoda is indicated by various remains of a gigantic reptile described in 1890 by the writer. The most characteristic portions examined are the caudal vertebræ, which in general form resemble those of *Diplodocus*. They are concave, below, as in the caudals of that genus, but the sides of the centra are also deeply excavated.

In the anterior caudals this excavation extends nearly or quite through the centra, a thin septum usually remaining. In the median caudals a deep cavity on each side exists, as shown in Figs. 24-26 below [like those of the original description except that a ventral view of the caudal vertebra is shown (Fig. 1, C)].

On page 241 of the same publication the genus *Barosaurus* is placed under the family Atlantosauridæ, which is thus defined:

A pituitary canal; large fossa for nasal gland. Distal end of scapula not expanded. Sacrum hollow; ischia directed downward, with expanded extremities meeting on median line. Anterior caudal vertebræ with lateral cavities; remaining caudals solid.

Genera *Atlantosaurus, Apatosaurus, Barosaurus, Brontosaurus.* Include the largest known land animals. Jurassic, North America.

A second species of *Barosaurus, B. affinis,* was named by Marsh as follows[1]:

These Atlantosaurus beds, though overlooked by many geologists, have a great development around the margin of the Black Hills, especially along the southern and eastern borders. The bones of gigantic dinosaurs mark the outcrop of this horizon at various points. The one best known, the writer explored personally in 1889, near Piedmont, South Dakota, and there obtained remains of an enormous dinosaur, subsequently named *Barosaurus.* During the past season, important parts of the rest of the type skeleton were secured for the Yale Museum, by G. R. Wieland of that University. With these fossils were found remains of a much smaller species, which may be called *Barosaurus affinis.*

As this paper was published the month of Professor Marsh's death, there was left to him no further opportunity for the elaboration of the description of either species, and that task has devolved upon his successors.

Locality and Horizon

The type specimens of *Barosaurus* were found in the eastern portion of the Black Hills, one and one-half miles east of Piedmont. The first specimen was discovered by Mrs. E. R. Ellerman, postmistress of Pottsville, on the land of Mrs. Rachel Hatch, a few rods southwest of the house. Thither Professor Marsh went, and, aided by Mr. J. B. Hatcher, secured the portion of the skeleton upon which he based the description published in 1890. In 1898, Professor Marsh directed G. R. Wieland to collect the remainder of the skeleton. This was done, and a large amount of material secured, including the remains of the smaller animal and a single carnivore tooth found in direct association with the larger specimen. Certain portions of the skeleton had, however, been removed as relics by the curious during the interim, but some of these were recovered by Doctor Wieland.

The formation is Morrison, which is exposed in a narrow outcropping flanking the uplift of the Black Hills. East of Piedmont the thickness is 220 feet,[2] rapidly decreasing to 70 feet in a nearby locality, while near Rapid it is 165 feet in thickness. Mook says further:

The name "Beulah shales" has been applied to the Morrison of the Black Hills region. The formation consists of the usual series of clays and shales, with thinner layers of sandstone and calcareous nodules. The prevailing color is gray, but other colors, such as red, maroon, pink, and purple, sometimes occur. Carbonaceous matter is sometimes present in the upper members.

In a letter to Professor Marsh, dated Piedmont, September 12, 1898, Wieland writes:

The skeleton runs through four vertical feet and the character of the clay changes frequently. Very little of the beautiful blue bone you showed me has been found. It is mostly black.

A diagram of the quarry as drawn by Wieland is here appended (Fig. 2).

Matrix and Inferred Habitat

A sample of the matrix was referred to my late colleague, Professor Barrell, who reported as follows:

[1] Footprints of Jurassic Dinosaurs. Amer. Jour. Sci., 3d ser., Vol. 7, 1899, p. 228.
[2] C. C. Mook. A Study of the Morrison Formation. Ann. New York Acad. Sci., Vol. 27, 1916, p. 100.

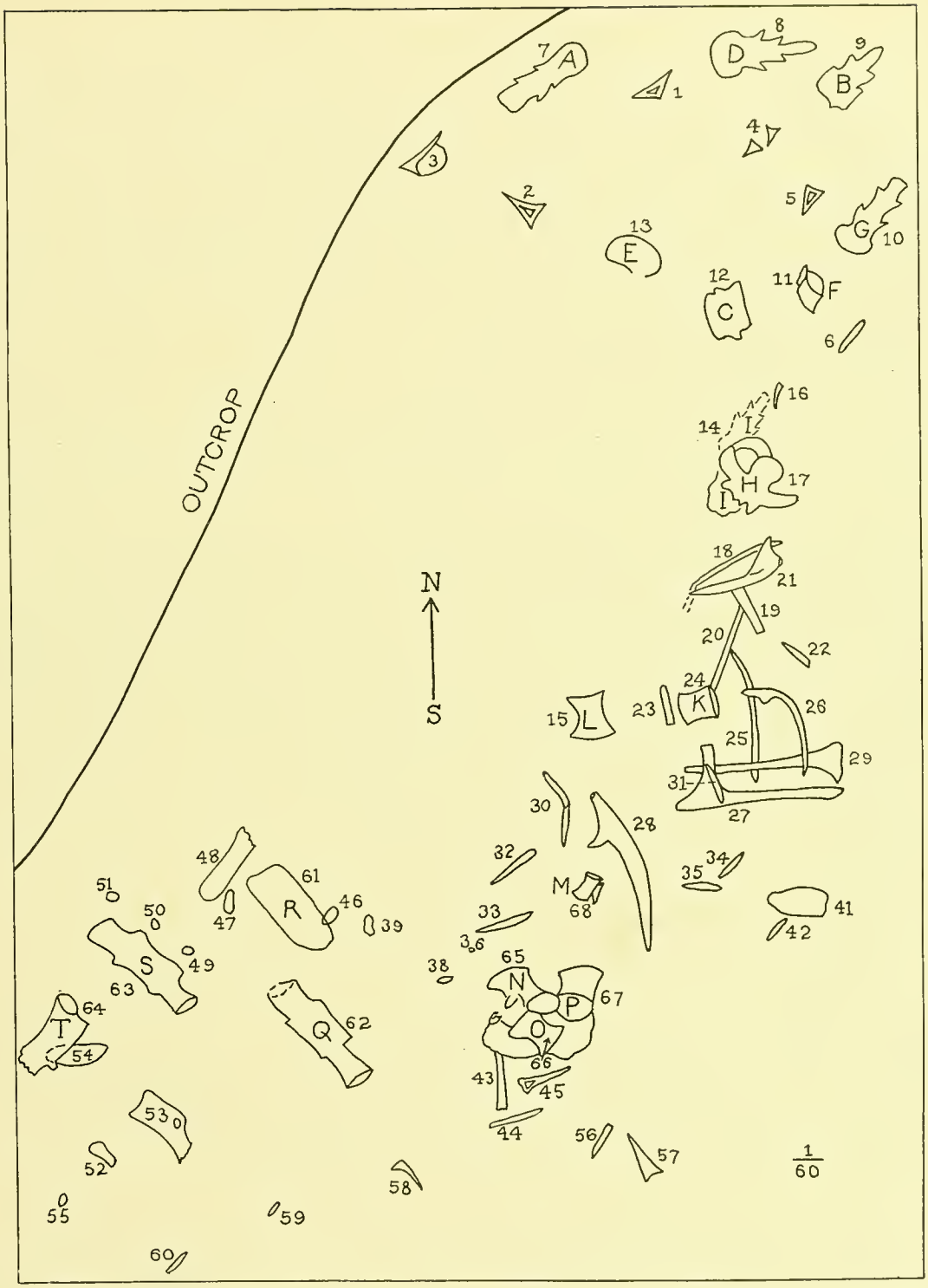


FIGURE 2.—Diagram of *Barosaurus* quarry. From sketch by G. R. Wieland 1898. Line of outcrop added from memory 1918. Scale about 1/60.

1-3, chevrons; 4, chevron(?); 5, chevron; 6, fragment; 7, vertebra A, caudal II; 8, vertebra D, caudal V; 9, vertebra B, caudal; 10, vertebra G, caudal IV; 11, vertebra F, caudal VI; 12, vertebra C, caudal VI; 13, vertebra E, caudal; 14, vertebra I, dorsal X; 15, vertebra L, dorsal V; 16, tooth of carnivorous dinosaur; 17, vertebra H, dorsal IV; 18-23, ribs; 24, vertebra K, caudal III; 25-29, ribs; 30, vertebræ fragments; 31-38, rib and other fragments; 39, small bone; 40, metacarpal from surface; 41, fragment of large bone; 42-44, fragments; 45, chevron; 46-51, fragments; 52, chevron?; 53, pubis; 54, sternal; 55, fragment; 56-57, ribs; 58, cervical rib, 15 in. long; 59-60, fragments; 61, vertebra R, cervical XV; 62, vertebra Q, cervical XIII; 63, vertebra S, cervical XII; 64, vertebra T, cervical XIV; 65, vertebra N, dorsal IX; 66, vertebra O, dorsal VII; 67, vertebra P, dorsal I; 68, vertebra M, caudal ca. XVII.

The rock consists of clay with the very finest silt, the grains of which are probably not more than .01 mm. in diameter. A fine grit was discernible in the clay, and an appreciable content of lime, as shown by a vigorous effervescence with acid. The gray clay shows occasional rusty stains from recent weathering, probably due to the presence of ferrous carbonate.

The inferred habitat was a rather swampy flood-plain, as water and organic matter must have been present to hold the iron in ferrous condition. Black specks which contained no grit seem to indicate plant material. These could not have been bone particles, as the bone is decidedly gritty; on the other hand, the decaying animal carcass may have been the source of the organic matter.

Material

The whole *Barosaurus lentus* individual must have been present originally, but was subject to dismembering and intermingling of the bones, possibly by carnivores, as the presence of the tooth might imply, even though there is no indication of tooth scoring on the *Barosaurus* bones. On the other hand, the confusion of the bones may have been due to the working of the entombing material in time of excessive moisture.

The bones are rarely injured other than by an oblique crushing, and some of the thinner laminæ and processes are delicate indeed. They lay scattered, although several dorsals were together at one end of the quarry, while the cervicals were at the other. It is entirely possible that the bones which are missing may have been lost by subsequent erosion, and that the specimen represents a single complete entombment, with a very slight intermingling of other bones (*Barosaurus affinis,* see below, page 38).

The material consists therefore of three specimens:

Barosaurus lentus Marsh, holotype. Yale Museum catalogue number 429. Of this specimen the following identified elements are present:

Cervicals 12-15	4
Dorsals 1, 4, 5, 7, 9, 10	6
Caudals 2-6, 13, 15-17, 19-20, 23, 25, 28, 32, ca. 42 and 70, also fragments ca. 12, 13	19+
Chevrons 5, 9, 16	3
Many ribs and rib fragments	ca. 10
Sternal, left	1
Scapula, part	1
Sacrum, part of centrum and coalesced neural spines	1
Portions of ilium	1
Pubis, right, part	1
Ischium, left, part	1
Femur fragments	1
Tibia fragments	1
Ends of left fibula	1
	51±

Barosaurus affinis Marsh, holotype. Yale Museum catalogue number 419. Of this species there are present:

Metacarpals	2

Theropod dinosaur, gen. et sp. indet. Yale Museum catalogue number 415.

Tooth	1

MORPHOLOGY OF *BAROSAURUS LENTUS*

Because of the paucity of material representing the other two species, and the fact that they do not surely belong to the genus *Barosaurus,* the type of *Barosaurus lentus* will be the principal subject for discussion.

Axial Skeleton

SKULL

The skull was unrepresented by a single fragment, nor are any of the anterior cervicals present; the presumption is, therefore, that the entire head and neck, except for the posterior portion, was swept away, possibly after entombment, as the cervical vertebræ which are preserved lay near the outcrop (see Fig. 2).

CERVICAL VERTEBRÆ

The four posterior cervicals are present. They are the estimated twelfth to fifteenth, the comparison being made with the mounted specimen of *Diplodocus carnegiei* at the Carnegie Museum at Pittsburgh. These cervicals resemble those of *Diplodocus* more than of any other genus in their general proportions and great length and also in the arrangement of the buttresses and laminæ. The lateral depressions, or pleurocœles, of the centra, while generally fully as deep as in *Diplodocus,* are not relatively so extensive in their antero-posterior dimension. The sequence of the vertebræ has been determined in part by the circumference of the posterior articular face of the centrum, which increases as follows: Cervical XII, 800 mm.; XIII, 840 mm.; XIV, 870 mm.; XV, 970 mm.; anterior face of dorsal I, 970 mm.

Cervical XII (Vertebra S) (Pl. II, Fig. 1).—This great bone has the longest centrum of any which are present, measuring no less than 930 mm. The vertebra is well preserved, although it has probably been subjected to a slight lateral crushing. It is, however, distorted the least of any of the cervicals present, with the exception of the fragmentary fourteenth.

The anterior face of the centrum is hemispherical, though somewhat laterally crushed. The surface of the bone, however, is removed, so that the interior cancellous tissue is exposed. The cancelli are very coarse. Ventrally, the centrum is characterized by a longitudinal groove enclosed by lateral carinæ which anteriorly pass into the capitular articulation for the rib. There is also a slight longitudinal lamina discernible for about one fourth the length of the centrum. The capitular facet is rather massive, and well braced antero-posteriorly.

The right lateral aspect of the bone bears a deep cavity or pleurocœle, the anterior limitation of which commences about the level of the diapophysis. This pleurocœle extends backward for a distance of about 240 mm., but is crossed by an oblique lamina of bone (pleurocentral lamina) running from above downward and backward. This lamina bifurcates at its anterior third and is in the line of the compression thrust from the prezygapophyses. The height of the pleurocœle is about 60 mm., and its greatest depth, at the anterior end, about 50 mm.

The prezygapophysis is preserved but displaced. Were it in its proper position, it would add considerably to the over-all length of the vertebra. The actual articular facet is very short antero-posteriorly, but wide transversely, and is somewhat convex upward in its transverse diameter.

The postzygapophysial facet is similarly short and wide; it is, of course, concave downward and outward (see Pl. II, Fig. 1, P. Z.).

The neural spine in this and the succeeding vertebræ is deeply bifid, with a median nodular excrescence for tendinous attachment at the bottom of the cleft. The spine rises about 110 mm. above the level of the tubercle on either side. The forward margin of the neural spine is continued as a thin ridge which forms a sweeping curve down to the prezygapophysis. The summit is somewhat thickened, and just beneath this thickening lie two pronounced cavities. A well defined posterior oblique lamina rises from the diapophysis and runs upward and backward to the superior limitation of the postzygapophysis. There is a distinct lateral depression just below this oblique lamina at its mid-length. The horizontal lamina is very pronounced, especially toward the diapophysis. It lies about at the level of the upper margin of the centrum.

Comparison with *Diplodocus carnegiei.*[3]—In comparison with the twelfth cervical of *Diplodocus carnegiei,* this bone differs in its much greater size, as shown by the table of measurements below, that of *Barosaurus* being over 50 per cent larger, especially in the central dimensions. The neural spine, however, is relatively somewhat lower. The pleurocœle of the *Barosaurus* cervical is much smaller relatively and is hardly as complicated; there is, however, the same oblique lamina dividing it into two portions, and in each instance this bifurcates anteriorly. One important difference lies in the position of the diapophysis, which in vertebræ XI and XII of *Diplodocus carnegiei* lies far forward, while in *Barosaurus* it lies more than one third of the distance back from the anterior end of the bone. Herein it resembles cervical X of *Diplodocus* much

Measurements of Cervical XII

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Length over all	1020	650*	1.57
Height over all	560	490†	1.15
Centrum, length	930	(600‡)–627*	1.48
" anterior face, height	216	165‡	1.31
" " " width	220§	210‡	(1.05)
" posterior face, height	273	200‡	1.36
" " " width	220	(228‡)–225*	(0.98)
" " " circumference	ca. 800	700‖	1.14
Pleurocœle, height	60		
" depth	ca. 50		
Index of total length to height	1.98	1.14	
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			1.33

* From Hatcher's measurements.
† From two figures, photograph gives 703.
‡ From O. A. Peterson's measurements.
§ Crushed.
‖ From J. B. Hatcher's figures, all measurements not being given.

[3] J. B. Hatcher, Diplodocus Marsh, its Osteology, Taxonomy, and Probable Habits, with a Restoration of the Skeleton. Mem. Carnegie Mus., Vol. 1, No. 1, 1901, p. 24, Fig. 7.

more than either XI or XII. The position of the diapophysis in *D. carnegiei,* however, is neither constant nor progressive, being so extremely far forward only in cervicals XI, XII, and XIII. In *D. carnegiei* it is the fourteenth cervical that has the longest centrum; in *Barosaurus* it is the twelfth.

Cervical XIII (Vertebra Q) (Pl. II, Fig. 2).—This is a huge bone, with very broad, wing-like expansions which bear the prezygapophyses and extend backward to the diapophyses about three-eighths of the distance from the anterior end of the centrum. These wing-like expansions measure 530 mm. in length, the width over both being about 570 mm. The ventral aspect of the centrum resembles that of cervical XII, except that instead of one median ridge there are two slight ridges which, while widely apart at the posterior end, converge opposite the diapophyses. Posteriorly, these ridges become about 50 mm. deep, and bound laterally the ventral aspect of the bone. The sides of the centra are also crossed by buttress-like horizontal laminæ which serve to strengthen the diapophyses and are continued beyond them into the wing-like expansions above mentioned. The latter are supported from beneath by a number of bracket-like expansions of bone, which give the inferior aspect of these plates an appearance of considerable complexity. The prezygapophyses are also widely expanded, the entire structure being doubtless correlated with considerable lateral movement of the neck in the region of the posterior cervicals.

The pleurocentral cavities, while deep, are less than one-fourth the length of the centrum, whereas in *Diplodocus carnegiei* the pleurocœle of the thirteenth cervical is nearer one-half the central length. In each instance it is crossed obliquely by the pleurocentral lamina, which, as in cervical XII, serves also to resist the thrust of the prezygapophysis.

Compared with *D. carnegiei,* therefore, the present bone is much larger, with proportionately smaller pleurocœles. The rib arises relatively further back and seems to have been somewhat lighter, if one may judge from the rib facets, as the actual rib is not preserved.

The neural spine is deeply bifid as in cervical XII. As the bone is now prepared, only the ventral and left lateral aspects are visible. A somewhat oblique view is shown on Plate II, Fig. 2.

Measurements of Cervical XIII

	Barosaurus lentus	*Diplodocus carnegiei*	*Ratios*
Length over all	1005†	655*	1.53
Height over all		550*	
Width across diapophyses	570	390*	1.46
Centrum, length	890	655*	1.36
" anterior face, height		186*	
" " " width	ca. 300‡	230*	1.30
" posterior face, height		220*	
" " " width	ca. 345‡	220*	1.57
" " " circumference	840	707	1.16
Pleurocœle, length	210		
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			1.40

* Peterson's measurements.
† Length increased by crushing?
‡ Measurements from photograph.

Cervical XIV (*Vertebra T*).—This bone is only partly preserved, the fragment consisting of the posterior part of the centrum, bearing the left postzygapophysis and a portion of the right. In this bone the lateral pleurocœle is further reduced and is shallow compared with that of cervical XIII. However, it is not entirely preserved. Its posterior limitation is 340 mm. forward of the hinder margin of the centrum. The lateral extent of the postzygapophysial facet is 195 mm. Ventrally the centrum is limited posteriorly by two rather deep longitudinal keels, as in *D. carnegiei.*

The circumference of the posterior face of the centrum is 870 mm., its horizontal diameter 300 mm., and the vertical one about 220 mm. The face is somewhat distorted, but does not exhibit the crushing shown in the other cervicals, hence these measurements have greater value.

Cervical XV (*Vertebra R*) (Pl. II, Figs. 3, 4).—This is a very well preserved bone, which, however, has suffered a dorso-ventral crushing so that, as in cervical XIII, not only are the ends of the centra apparently too broad for their height, but they appear obliquely sheared, the dorsal margin of the posterior face being at least 100 mm. in advance of the ventral. To what extent the obliquity of the articular faces in these cervicals is actually due to crushing is difficult to conjecture, for in *D. carnegiei* it is very slight, although greatest in cervicals XIV and XV, especially the latter. It may well be that in *Barosaurus* this obliquity was more marked, and correlated with a greater vertical range of movement of the neck (see below, page 15 and Pl. VII, description). The postzygapophyses and the bifid neural spine are missing to the base of the cleft.

The prezygapophyses are borne on very broadly expanded wing-like laminæ which also bear laterally the tubercular facets for the ribs. These laminæ are very thin, except forward where they thicken to bear the weight of the zygapophyses. Elsewhere the laminæ are supported by radial bracket-like buttresses, especially deep ones running from the centrum to the rib facet or diapophysis (see Pl. II, Fig. 4). The latter is again not so massive as in *Diplodocus carnegiei,* but has the same relative position, about mid-length the entire vertebra as it is now preserved.

The relative position of the two rib facets differs in this vertebra from that in any other *Barosaurus* cervicals which are present, as well as from that in the fifteenth cervical of *Diplodocus carnegiei,* in that the capitular facet lies *behind* the tubercular at least 50 mm.; in all the other cervicals mentioned the capitular lies in front. To what extent, if any, this is due to an oblique shearing is not apparent; it seems, however, to be significant and in harmony with the great obliquity of the articular faces of the centrum.

The pleurocœles are neither so deep nor so conspicuous as in the twelfth centrum, where they reach their greatest depth among the preserved cervicals. The posterior limit of the left pleurocœle is about 300 mm. forward of the margin of the posterior face of the centrum.

Oblique laminæ running in the wake of the anterior zygapophyses are very widely developed. These serve posteriorly to buttress the expanded articular face. From this, thin horizontal laminæ run out along the posterior face of the diapophysis and thus form the hinder margin of the expanded, wing-like plates.

Measurements of Cervical XV

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Length over all	960*	590†	1.62
Height over all		ca. 585†	
Width across diapophyses	760	520†	1.46
Centrum, length	720	590†	1.22
" posterior face, height	200*	233†	0.86
" " " width	365	255†	1.43
" " " circumference	970	759	1.27
Pleurocœle, length	ca. 160		
Prezygapophysis to rib facet	450	352	1.27
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			1.30

* Probably exaggerated by crushing.
† Furnished by Peterson. Other measurements from figures.

DORSAL VERTEBRÆ

Dorsal I (Vertebra P) (Pl. III, Figs. 1-3).—A fairly well preserved bone. Such portions as are lacking on one side, however, are fortunately preserved on the other. As compared with the fifteenth cervical, the first dorsal is much shorter, the centrum of the latter measuring but 470 mm., as against the 720 mm. of the former, nor are the anterior wing-like expansions—horizontal laminæ—of so great antero-posterior extent, although their over-all width is nearly as great. The centrum shows much the same curvature of articular ends as does that of cervical XV, which is also true of their obliquity, especially of the posterior face. This obliquity is markedly greater than in *Diplodocus carnegiei,* and while doubtless due in part to crushing, as in cervical XV, it also seems to indicate a greater vertical flexion than is usual with sauropod dinosaurs. The seventh cervical of the Camelidæ is similarly modified, and also shows, in the llama at least, a marked dorso-ventral flattening of centrum similar to that of the first dorsal of *Barosaurus.* The convexity of the anterior face of the present bone is considerably less than in *Diplodocus,* but herein again the bone may not be quite normal. It may, however, be correlated with less mobility of movement at this point.

The pleurocœles are relatively much larger than in the cervicals, occupying approximately one-half of the centrum length. Their depth is also great, although its precise limit may not be ascertained, as the median separating wall has been destroyed and the two pleurocœles are confluent. Above, the pleurocœle is bounded by a thin, horizontal lamina of bone which serves to buttress both articular faces as they expand, the centrum being markedly constricted in the middle portion.

The prezygapophyses are wide, more like those of the cervicals, while the postzygapophyses are more dorsal-like, although with as yet no trace of the hyposphene-hypantrum articulation characteristic of the later dorsals. Width of the right prezygapophysis, measured on the curve, 230 mm.; of the left, 240 mm., showing the asymmetry characteristic of these forms. Length of the left postzygapophysis, the one preserved, 140 mm. There is the same nodular insertion for a longitudinal tendon lying at the bottom of the cleft of the neural spine as in the cervicals. A continuation of this nodule extends downward on the rear side of the bone as a distinct ridge, the

postspinal lamina, for about 100 mm. There is an equivalent prespinal lamina, much less pronounced, and about 60 mm. long. In the later dorsals these laminæ become highly rugose and of equal dimensions front and rear. They must have formed the insertions of powerful connecting tendons, the principal extension members of the fabric (see Pl. III, Figs. 1 and 2, PR.L. and PO.L.). The first dorsal of *Barosaurus* is thus transitional in character between the typically cervical and dorsal vertebræ.

As compared with the first dorsal of *Diplodocus,* that of *Barosaurus* is characterized by a relatively shorter centrum, with proportionately somewhat larger pleurocœles and more pronounced horizontal laminæ on the centrum. The bone in *Barosaurus* appears less massive, that is, more deeply sculptured and lightened. The position of the rather small capitular rib facet near the lower margin of the centrum is essentially the same. That of the tubercular facet must also have been similar, but in this instance the actual facet is not preserved.

Measurements of Dorsal I

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Length over all	620	600*	1.03
Height over all	590†	680*–638	0.87
Width across diapophyses		610*	
Centrum, length	470	525*	0.89
" anterior face, height	165	250*	0.66
" " " width	328‡	265*	1.24
" " " circumference	772§	809§	0.95
" posterior face, height	250	250*	1.00
" " " width	350	245*	1.42
" " " circumference	980	780*	1.25
Pleurocœle, length	195		
" height	59		
Width across prezygapophyses	530	440	1.20
Width across postzygapophyses	460	374	1.23
Neural spine, depth of cleft	246		
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			1.06

* Peterson's measurements; others taken from Hatcher's Plate VII.
† Reduced by crushing.
‡ Taken from photograph, not original.
§ Calculated.

Dorsal IV (Vertebra H) (Pl. III, Figs. 4-6).—This bone is well preserved except for the neural spines and the distal ends of the diapophyses, and shows but little crushing. In certain respects it resembles dorsal III of *Diplodocus,* in others dorsal IV. It resembles dorsal III in the position of the capitular rib facet, which is borne on the upper margin of the centrum. This bone also resembles dorsal III in general proportions, but differs mainly in that the postzygapophyses are complicated by the presence of an hyposphene-hypantrum articulation as well. This supplementary articulation first appears in dorsal IV of *D. carnegiei.* The centrum of the bone under consideration is short, with deep but small pleurocœles, their small size being due to their being partly obliterated by the capitular rib facets somewhat as in dorsal III of *Diplodocus.* In dorsal IV of *Diplodocus,* however, the large facet almost completely obliterates the

pleurocœle as seen from the side. In *Brontosaurus* also the hypantrum first appears on the fourth dorsal. The pleurocœle in *Barosaurus* is bounded above by a thin lamina of bone running to the upper margin of the rib facet, whereas in *Diplodocus* this lamina is unrepresented, the bone being thickly rounded where it would lie.

From the anterior aspect (Pl. III, Fig. 4) the bone exhibits an oblique crushing, but is otherwise intact except for a portion of the margin of the articular face. The latter is still decidedly convex. Above the neural canal rises a vertical lamina which supports, bracket-like, a shelf which in turn connects with the two prezygapophyses. From each of these arises a lamina (prezygapophysial lamina) which buttresses the anterior face of the neural spine, but fades out below the level of the crest. The median roughening for tendinous attachment, the prespinal lamina, extends from the neural cleft downward to the connecting shelf, a distance of 150 mm. The width of the spine at the level of the cleft is 190 mm.

The posterior aspect (Pl. III, Fig. 5), as has been said, is the first to show the hypantrum. This conforms with the hyposphene of the next vertebra to be discussed, which can not be forward of the fifth in series. The centrum face is well preserved and is markedly concave. The hypantrum is supported from below by a single bracket-like lamina which arises from the neural canal, where it bifurcates to form an arch over the opening. There are some depressions on the anterior face of the expanded portion of the bone just beneath the zygapophyses, but no distinct buttresses arise, as they would doubtless have impeded the intervertebral motion. The rugose postspinal lamina is of less vertical extent than the prespinal, but is more prominently raised above the level of the bone. Its vertical extent is about 80 mm. The diapophyses are strong and broad and well supported by the diapophysial laminæ.

Measurements of Dorsal IV

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Length over all	290*	260*	1.11*
Height over all	760†	770§‡	0.99
" to base of cleft	543		
Width across diapophyses		750§	
Centrum, length	260	240§	1.08
" anterior face, height	220	250§	0.88
" " " width	290	278§	1.04
" " " circumference	880		
" posterior face, height	235	275§	0.85
" " " width	330	335‖	0.98
" " " circumference	920		
Neural canal, height	40		
" " width	48		
Width across prezygapophyses	265		
Width across postzygapophyses	300		
Postspinal lamina rugosity, vertical length	80		
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			0.99

* From photograph.
† Estimated.
‡ 718 (Hatcher).
§ Peterson's measurements.
‖ Somewhat abnormal due to crushing (Peterson).

Dorsal V (*Vertebra L*) (Pl. IV, Figs. 1-3).—This bone is fairly well preserved except for the neural spine and diapophyses. The centrum, as usual, is obliquely crushed, so that the anterior face of it has been shifted to the left. This is the first vertebra to show the hyposphene or anterior accessory articulation, dorsal IV showing but the hypantrum. In dorsal V, the entire articulation is very massive and well buttressed. This vertebra also shows a cleft spine, but the bottom of the cleft is very materially higher than in the fourth. The capitular rib facets are now clear of the centrum, being borne entirely upon the pedicel of the neural arch; they are, however, lower than in the corresponding bone of *Diplodocus*. The two laminæ which support the prezygapophyses (prezygapophysial laminæ) have their origin in the rib facet and transmit a thrust direct from rib to zygapophysis. The centrum is as deeply opisthocœlous as are its predecessors.

Two laminæ, as before, arise from the shelf between the zygapophyses and run upward, diminishing as they go; then, becoming accentuated again as the spine becomes lightened, they exhibit the marked asymmetry to be emphasized in vertebræ VII and IX (see below and Pl. IV, Figs. 1, 3). The tendinous roughenings, the pre- and postspinal laminæ, are not very pronounced, but run up the entire face of the spine to the base of the cleft.

Lateral aspect (Pl. IV, Fig. 2).—The pleurocœles are apparently very deep but are filled with matrix. They are proportionately but slightly smaller than in dorsal V of *Diplodocus*. The capitular facets overhang them slightly and look somewhat downward and backward. The diapophysis is well supported, as the thin anterior and posterior diapophysial laminæ buttress it from below, and it is connected with the prezygapophysis by the horizontal lamina. Of the diapophysial laminæ the anterior one arises just above the rib facet, the posterior one nearer the hinder margin of the centrum, the two converging beneath the diapophysis. Between the anterior diapophysial, the horizontal, and the oblique laminæ of the prezygapophysis there is a very deep depression, extending nearly to the central plane of the bone.

The posterior aspect (Pl. IV, Fig. 3) is very well preserved and has suffered less from crushing than has the anterior face. The centrum shows, in its present condition, less concavity than that of dorsal IV and less than the immediately succeeding ones. Two of the latter have suffered lateral crushing instead of the antero-posterior shearing strain as in the present instance, which probably accounts for their increased curvature.

The neural arch is narrowest across the pedicels, above which it expands very widely to support the diapophyses, the surface of the bone showing but few inequalities. There arises a median buttress, the postzygapophysial lamina, just above the neural canal. This increases in width from nothing to 9.6 mm. as it rises. The average width of the buttress, however, is but 8 mm., except just beneath the hypantrum. The height of the zygapophysis above the centrum is about 240 mm. Greatest width across hypantra, 93.5 mm.; least, 23.5 mm. Greatest width across zygapophyses, 265 mm.

There is a curious asymmetry in the spine as viewed from the rear, in that on the left side there is a large oval depression (Pl. IV, Fig. 3, D) about 60 mm. wide, which is almost entirely lacking on the right. The rugose postspinal lamina is pronounced, and while it rises but little above the general level of the bone, it has a length of 188 mm.

Measurements of Dorsal V

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Height over all	840†	845*	0.99
Height of neural arch to cleft of spine	473		
Height at postzygapophysis	514	500	1.03
Centrum, length	ca. 310	245*	1.26
" anterior face, height	200‡	280*	0.71
" " " width	320	278*	1.15
" posterior face, height	255	250*	1.02
" " " width	320	295*	1.08
" " " circumference	940	844§	1.11
Pleurocœle, length	60		
" height	ca. 80		
Neural canal, height	43		
" " width	50		
Width across pedicels	200		
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			1.04

* Peterson's measurements.

† Estimated.

‡ Error from crushing and lack of preservation considerable, as opposing face of dorsal IV = 240.

§ Calculated.

Dorsal VI (Pl. VI, Fig. 3).—This vertebra seems to be represented by the summit of the neural spine only, with no identifiable trace of the remainder of the bone in the collection. The bone fragment is very heavy and rugose, and may well have formed the common anchorage for the paired muscles and tendons of the bifid spines in front. This from its appearance is assumed to be the first unpaired spine. In *Brontosaurus,* the first uncleft spine which is broad and heavy like the one under consideration is borne by the sixth dorsal, in *Diplodocus carnegiei* by the seventh, and even there and in the eighth and ninth the summit is slightly cleft. In *D. longus* at the American Museum of Natural History the spine of dorsal VI is the last bifid one, and, as in the Pittsburgh specimen, the succeeding ones are slightly notched and not straight-topped as in *Barosaurus.* In *Brachiosaurus* none of the dorsals shows a bifid spine. In this feature, therefore, the resemblance is with *Brontosaurus* rather than with either *Diplodocus* or *Brachiosaurus.*

Breadth of the neural summit, 190 mm.; its antero-posterior diameter, 92 mm.

The development of the heavily rugose pre- and postspinal laminæ gives this bone fragment a distinct tripartite character, as though it formed not alone the origin of the great paired muscles of the neck, but short and powerful median tendons connecting with the spinal lamina of the preceding and succeeding vertebra.

Dorsal VII (*Vertebra O*).—This bone, while complete as to its dorsal spine, lacks the diapophyses and is otherwise seriously crushed and mutilated. The spine has suffered a curious torsion, but was asymmetrical even in life, as the prezygapophysial lamina on the left side is very much narrower than on the right; their respective widths being 3 mm. and 22.3 mm.

Anterior aspect.—The anterior face of the centrum is badly crushed, so that its original width may not be ascertained. The neural arch has diminished in width, being but 115 mm. across the pedicels as compared with 230 mm. for dorsal V. The pre-

zygapophyses are preserved, although the right one is displaced. They still show the hyposphene articulation, but the entire structure is small and weak compared with that of dorsal V.

Lateral aspect (left).—The centrum has been crushed out to a greater than normal length, measuring about 300 mm. The pleurocœle is well developed, but rather high on the centrum. There is a faint indication of the capitular rib facet on the left prezygapophysis. It is more decided on the right, where a distinct limitation may be seen. The inference is that the rib head was light, the tubercular being the chief articulation—this last, however, can not be verified, as the diapophyses which bore the tubercular facets are missing.

The various lateral laminæ are well developed, the anterior oblique and diapophysial laminæ being the dominant ones, as they overlie the posterior oblique. The last has its origin on the forward end of the centrum and runs directly upward and backward to the postzygapophysis. Where it crosses the pedicel, it divides and aids in reinforcing the diapophysis.

The posterior aspect is so remarkably distorted that a description of it would have but little value.

*Measurements of Dorsal VII**

	Barosaurus lentus mm.
Length over all	290
Height over all	800
Centrum, length	270†
" anterior face, height	245
" posterior face, height	280
" " " width	240†
Height to prezygapophyses	480
Height to postzygapophyses	530

* Dorsal VII of *Diplodocus carnegiei* is a plaster restoration, hence measurements are not given.
† Altered by crushing.

Dorsal IX (Vertebra N) (Pl. IV, Figs. 4-6).—This vertebra, as usual, lacks the diapophyses, otherwise it is fairly perfect, although somewhat obliquely crushed. It differs from that just described in having somewhat heavier prezygapophyses, with a distinct capitular rib facet on their outer aspect at the level of the zygapophysial facet. There is the same peculiar asymmetry on the forward face of the spine as in dorsal VII, but reversed. The vertebra is crushed in the reverse way also, which may heighten the apparent asymmetry but can not entirely account for it. The neural spine is very tall, forming 370 mm. of the height of the entire vertebra. Laterally, the latter broadens materially, due to the development of the diapophysial laminæ, although the entire outline is not preserved as shown in the figure (Pl. IV, Fig. 5).

The anterior face of the centrum is rather flat, but the posterior one is deeply concave, due, however, in large part to crushing.

Lateral aspect, right (Pl. IV, Fig. 5).—The pleurocœle is large and high, and is situated well forward, so that the oblique lamina which bounds it forms the upper hinder margin and is very heavy. The zygapophyses are strong and well buttressed and the hypantra are still well developed, though closely approximated. Laminæ, much as in *Diplodocus carnegiei,* arise high up under the diapophyses.

Measurements of Dorsal IX

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Length over all	255	355*	0.72
Height over all	850	1028*	0.83
Width across diapophyses		475*	
Centrum, length	±212†	245*	0.87
" anterior face, height	260	275*	0.94
" " " width	240+	295*	0.81
" posterior face, height	280	295*	0.95
" " " width	305	310*	0.98
" " " circumference	980	980*	1.00
Neural canal, height	35		
" " width	55		
Width across pedicels	160		
Width across prezygapophyses	445		
Height to prezygapophyses	480		
Width across postzygapophyses	225		
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			0.89

* Peterson's measurements.
† From photograph.

Dorsal X (Vertebra I).—This bone has a well preserved centrum; the posterior portion above the centrum, however, is missing from a point a little above the neural canal, including the postzygapophyses and the entire spine. The prezygapophyses and a small portion of the left diapophysis remain.

Right lateral aspect.—There is a well developed pleurocœle within the limits of the centrum. It is divided by a partition into a deeper forward and a lesser and more shallow hinder portion.

Anterior aspect.—This shows the outline of the centrum not quite complete.

Posterior aspect.—The face of the centrum is but slightly concave.

Measurements of Dorsal X

	Barosaurus lentus mm.	*Diplodocus carnegie* mm.	*Ratios*
Length over all		365*	
Height over all		1070*	
Width across diapophyses		495*	
Centrum, length		290*	
" anterior face, height	265	ca. 305*	0.87
" " " width	260	ca. 335*	0.78
" posterior face, height	280	312*	0.90
" " " width	290	325*	0.89
Pleurocœle, length	95		
" height	80		
Neural canal, height	52		
" " width	58		
Width across pedicels	230		
Width across prezygapophyses	240		
Distance between prezygapophyses	30		
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			0.86

* Peterson's measurements.

SACRUM

This element is represented by a portion of the fourth(?) centrum and the coalesced summits of the neural spines. The central fragment is extremely massive, with no adaptation for lightening the weight appreciable in the portion preserved. Measurements of the centrum are impracticable.

The coalesced neural spines are sheared off on the apparent left side so that their buttresses are lacking. On the other side, however, there are three such buttresses which are in part free from the mass of the bone, like the flying buttresses of Gothic architecture. The entire summit is quite rugose, the rugosity extending down on the buttresses for a distance of about 100 mm.

The antero-posterior diameter of the mass as preserved is 240 mm.; the preserved height 390 mm., with no trace of zygapophyses at the level of fracture.

There is an additional rugose nodular piece of bone which fits fairly well into the somewhat cleft anterior end of the coalesced spinal summits and seems to represent such a nodule as that figured by Osborn[4] in the sacrum of *Diplodocus longus* at the American Museum, as well as in the restoration of *D. carnegiei.*

The equivalent measurements of the coalesced neural spines of *Barosaurus* and the two *Diplodocus* specimens are:

	Barosaurus lentus mm.	*Diplodocus longus* mm.	*D. carnegiei* mm.
Antero-posterior diameter	240	113.6	156
Height from zygapophysis	390+	340	450

The much greater first dimension in *Barosaurus* seems to point to need for a firmer anchorage for the extension members of the entire vertebral fabric, correlated probably with the greater weight of the cervical region. (See Pl. VII.)

CAUDAL VERTEBRÆ

Caudal II (Vertebra A).—This bone has a fine centrum showing little apparent distortion. But little of the neural arch is present and the wing-like diapophyses are gone. This vertebra is procœlous, but the curvatures are not great. Height of the neural canal, 36 mm.; its width, 44 mm. The lateral aspect shows deep pleurocœles, that of the right side having a length of 72 mm. to a depth of 173 mm. The neural arch has not the proportionate antero-posterior diameter seen in the dorsals. The least diameter across the pedicels is 69 mm.

Posterior aspect.—The right postzygapophysis is preserved, and corresponds in size and curvature to the equivalent prezygapophysis of the vertebra next to be described. The zygapophysis is supported by the usual postzygapophysial lamina rising above the neural canal. The latter, however, is distorted by crushing. Its height is 46 mm.

[4] H. F. Osborn, A Skeleton of Diplodocus. Mem. Amer. Mus. Nat. Hist., Vol. I, Pt. V, 1899, Fig. 7.

Measurements of Caudal II

	Barosaurus lentus mm.
Centrum, length	172
" anterior face, height	280
" " " width	385
" " " circumference	1010
" posterior face, height	245
" " " width	315
Pleurocœle, length	72
" depth	173
Neural canal, height	36
" " width	44
Width across pedicels (maximum)	128
Height to prezygapophyses	435
Height to postzygapophyses	410

Caudal III (*Vertebra K*) (Pl. V, Figs. 1-3).—This bone is very finely preserved even to the diapophyses, the more perfect right one being supplemented completely by the left.

The anterior face of the procœlous centrum is deeply concave, the ratio of depth to width of the curve being about 1 : 4. This may be very slightly exaggerated by crushing. The neural arch is strong. Heavy buttresses, prezygapophysial laminæ, support the zygapophyses, reinforced by lighter oblique ones, which originate above the neural canal, where they arise as the keystone of the arch which overhangs the aperture of the canal. The prezygapophyses are well developed and face inward and upward at an angle of about 45 degrees. Above them rises the neural spine, somewhat asymmetrical as in the posterior dorsals, especially as to the position of the rugose prespinal lamina. The diapophyses have a ventral, more or less horizontal portion, upon which there arises at right angles a thin, expanded, vertical plate; this in turn is bounded on its outer margin by the rugose diapophysial lamina, which is expanded antero-posteriorly. A strong oblique buttress arising from the pedicel runs across the anterior face of the otherwise thin diapophysial plate, and abuts against the inner side of the lamina in its upper portion. Width across zygapophyses, 180 mm. Vertical extent of right diapophysial lamina, 280 mm.

Lateral aspect (right) (Pl. V, Fig. 2).—The centrum has a very deep pleurocœle, partially occluded by matrix. The pleurocœle lies in the upper half of the centrum. The large diapophysis overhangs the side of the centrum, and in front of the diapophysial plate there is another pleurocœle-like depression impressed into the pedicel as well as the upper portion of the centrum. This is also occluded by matrix, so that its depth may not be learned, but its height is 90 mm. and the antero-posterior diameter 67 mm. The neural spine is inclined slightly backward, so that it overlies the rear half of the centrum. The spine is reinforced by thin laminæ of bone. The diapophysial lamina rises vertically from the diapophysis, and another, almost horizontal one originates about the same place and runs to the postzygapophyses. There is a heavy rugosity on the upper half on the lateral aspect of the spine, which is deeply channeled to reduce weight.

The posterior aspect is not so well preserved, as distortion is in greater evidence than in front. The width across the pedicels is 125 mm.; of the neural canal, 45 mm.; its height, 45 mm. (Compare table below.)

Measurements of Caudal III

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Length over all	236	278*	0.85
Height over all	705	920†	0.77
Width across diapophyses	560	670†	0.84
Centrum, anterior face, height	242	324*	0.75
" " " width	345	‡	
" " " circumference	965	‡	
" posterior face, height	190	275†	0.69
" " " width	340	335†	1.01
Pleurocœle, length	ca. 100		
" height	60		
Neural canal, height at anterior face	30		
" " width " "	43		
Width across pedicels " "	220		
Width across postzygapophyses	930		
Neural spine, width (least)	72.8		
" " width of summit	110		
Diapophysial lamina rugosity, length	280		
" " " width	ca. 70		
Postspinal lamina rugosity, vertical length	360		
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			0.82

* Calculated from photograph.

† Peterson's measurements.

‡ Bone coössified with II in *D. carnegiei,* hence no measurement.

The postzygapophyses are supported by a median bracket-like buttress which arises above the neural canal and bifurcates, one branch going to each zygapophysis. The latter face downward and outward at an angle of 45 degrees, so that their faces are at right angles to each other. The left facet is nearly flat, while the right curves through 90 degrees of arc. From the postzygapophyses, strong but thin buttresses arise to reinforce the lateral margins of the neural spine (postzygapophysial laminæ). There are also broad, horizontal ridges from the inner face of the postzygapophyses which converge upon the spine. (See Pl. V, Fig. 3.)

The centrum of the specimen of *Diplodocus longus* in the American Museum of Natural History is more nearly circular, those of *D. carnegiei* and *Barosaurus* agreeing in proportions, hence probably more nearly normal. The main distinction of the *Barosaurus* caudal III, aside from its smaller size, seems to be the non-cleft spinous process, which is slightly bifid in both species of *Diplodocus.*

Caudal IV (Vertebra G).—This bone is well preserved, save that the diapophyses are lacking with the exception of the upper portion of the right.

Anterior face.—The centrum seems larger than that of caudal III and the prezygapophyses are heavy and wider apart. It is probable, however, that crushing has somewhat exaggerated this. The concavity of the anterior face of the centrum is also greater than in III. There is little to distinguish this bone from its predecessor.

Lateral aspect.—The spine in its present condition slants somewhat more than in caudal III. The pleurocœle is large, and very deep, and lies in the upper half of the centrum.

Rear aspect.—Centrum somewhat crushed. Width of neural canal at posterior end, 50 mm.; its height, 50 mm.

Meosurements of Caudal IV

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Length over all		275*	
Height over all	650	865*	0.75
Width across diapophyses		585*	
Centrum, length	208	215*	0.97
" anterior face, height	245	298*	0.82
" " " width	370	335*	1.10
" " " circumference	1012		
" posterior face, height	220	272*	0.81
" " " width	333	328*	1.01
Pleurocœle, length	99		
" height	68		
Neural canal, height at anterior face	46–50		
" " width " "	45–50		
Width across prezygapophyses	ca. 230		
Width across postzygapophyses	225		
Neural spine, width of summit	108		
Postspinal lamina rugosity, vertical length	345		
Average ratios: *Barosaurus lentus* and *Diplodocus carnegici*			0.91

* Peterson's measurements.

Caudal V (Vertebra D).—The centrum and right diapophysis are preserved intact. The remainder, above the neural canal, is missing, except that a portion of the disconnected spine is preserved.

Anterior aspect.—Vertical height of diapophysial lamina, 230 mm. Height of spine above the prezygapophyses, estimated at 320 mm.

Measurements of Caudal V

	Barosaurus lentus mm.	*Diplodocus carnegici* mm.	*Ratios*
Length over all		265*	
Height over all		835*	
Width across diapophyses	595†	544*	1.09
Centrum, length	219	200*	1.09
" anterior face, height	253	290*	0.87
" " " width	355	335*	1.06
" posterior face, height	216	263*	0.82
" " " width	318	320*	0.99
Neural canal, height	46		
" " width	40		
Average ratios: *Barosaurus lentus* and *Diplodocus carnegici*			0.99

* Peterson's measurements.
† Estimated.

Caudal VI.—This bone seems to be represented by vertebræ F and C. Of the former only a portion of the centrum with the neural arch and spine is present, and of the latter a supplementary part of the centrum. They show no remarkable characteristics which would tend to differentiate them from caudal V. Another fragment of a centrum is also present which was evidently adjacent to the others in the living animal.

Caudal XIII.—From caudal VI to the estimated thirteenth none are preserved entire, although certain fragments of centra may pertain to intervening bones. The thirteenth,

however, is nearly perfect, except for the rarely preserved diapophyses, of which only a portion of the left is present. This *Barosaurus* caudal differs from that of *Diplodocus,* moreover, in that the diapophyses arise lower down on the vertebra, being almost entirely below a line drawn from the upper limitations of the faces of the centra, whereas in both *D. carnegiei* and *D. longus* of the American Museum the diapophysis arises above a line thus drawn. In *D. longus* the entire diapophyses are visible when viewed on a level from in front, in *Barosaurus* they are hidden by the expanded faces of the centrum. The centrum is deeply constricted in the middle, with a concave anterior face and a flattened posterior one. Laterally it bears deep pleurocœles which are relatively long and low. In the present instance, the median partition between the pleurocœles is broken through, but in the succeeding caudal it is about 20 mm. thick, which must have been approximately true of the present bone. There is on the under face of the centrum the longitudinal hollowing so characteristic of *Diplodocus.* In fact, in Marsh's description of that genus (1878, p. 414) he says: "It may be distinguished from the genera already known by the caudal vertebræ, which are elongated, deeply excavated below, and have double chevrons, with both anterior and posterior rami"—a definition which would apply equally well to *Barosaurus.* The median hollow is accentuated as one goes further back in the caudal series. The neural arch is strong; the spine, slanting backward at an angle of 45 degrees, is expanded and rugose at the summit. The width of the summit is 96 mm., and the antero-posterior diameter 126 mm. Beneath the expanded portion the transverse diameter is 42.5 mm. Prominent but thin buttresses, the prezygapophysial laminæ, run up the front of the spine, the prespinal lamina being confined between them except toward the summit, where it expands to meet the terminal rugosity. The prezygapophyses are well developed, jutting about 65 mm. in front of the centrum. The articular face looks upward and inward at an angle of 45 degrees and is comparatively flat. The postzygapophyses underlie the spinous process and do not extend beyond the limits of the centrum. Their articular faces are somewhat curved and look downward and outward. Both pre- and postzygapophyses are well buttressed from the pedicels by the zygapophysial laminæ.

The centrum is procœlous, the curvature of the anterior face being such that the ratio of the depth of the concavity to its width is as 1 : 8. There are well marked chevron facets at the posterior end of the centrum, which seem to imply a backwardly directed chevron similar in angulation to the spine.

In *Diplodocus longus* the spine is much more erect than in *Barosaurus* nor is the summit expanded as in the latter genus.

Measurements of Caudal XIII	*Barosaurus lentus* mm.
Height over all	445
Centrum, length	245
" anterior face, height	215
" " " width	252
" posterior face, height	216
" " " width	220
Pleurocœle, length	100
" height	35
Neural spine, width of summit	96

Caudal XV (Pl. V, Figs. 4, 5).—This bone shows but little distinction from caudal XIII, and is about as perfect in its degree of preservation.

Measurements of Caudal XV

	Barosaurus lentus mm.
Length over all	340
Height over all	420
Centrum, length	245
" anterior face, height	217
" " " width	247
" posterior face, height	200
" " " width	240
Pleurocœle, length	135
" height	35
Neural canal, height (anterior end)	31.5
" " width " "	42
Neural spine, width of summit	84.4
" " length " "	112.5

Caudal XVI.—Centrum only preserved. The longitudinal cavity beneath the centrum is becoming more pronounced, while the curvature of the anterior face is less, its depth being to the width as 1 : 15. The pleurocœle is still distinct and has the form of quite a deep conical depression. The posterior face of the centrum is somewhat concave.

Measurements of Caudal XVI

	Barosaurus lentus mm.
Centrum, length	255
" anterior face, height	205
" " " width	220
" posterior face, height	195
" " " width	235
Pleurocœle, length	150

Caudal XVII (Pl. V, Fig. 6).—This is a splendidly preserved bone except for the diapophyses. Of the centrum, neither face is much curved, but the anterior aspect is slightly more concave. The pleurocœle is still well developed and the inferior concavity of the centrum is becoming pronounced. Well developed chevron facets are present, of which the posterior are still the more prominent.

Both anterior and posterior zygapophyses overhang the centrum, the former to a greater extent than the latter. The neural arch is low, the spine, however, rising well over the after end of the centrum, and jutting about 50 mm. beyond it posteriorly. The summit of the spine differs decidedly from that of caudal XV, as it is not so highly rugose, and the curve of the summit is semicylindrical, with the long axis antero-posterior. The summit slopes downward gently toward the rear. The insertions for the longitudinal interspinose ligaments on front and rear face are still well developed and rugose. Laminæ from the prezygapophyses run almost horizontally backward, gradually rising to reinforce the spine.

Caudal XVIII seems to be missing from the series, the discrepancy in proportions between the one just described and the next preserved being too great to admit of their being contiguous.

Measurements of Caudal XVII

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Length over all	355	345*	1.03
Height over all	350	530*	0.66
Width across diapophyses	?	200*	
Centrum, length	270	277*	0.97
" anterior face, height	187	204*	0.92
" " " width	220	200*	1.10
" posterior face, height	180	204*	0.88
" " " width	210	195*	1.08
" " " circumference		ca. 670*	
" mid length, width	130		
Pleurocœle, length	170		
Neural canal, height	27		
" " width	30		
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			0.95

* Peterson's measurements.

Caudal XIX.—This is a very well preserved bone, characterized by a total absence of diapophyses, which in *Diplodocus longus* cease at the twenty-second caudal, and by the reduction in depth of the pleurocœles. The bone is both proportionately and actually longer than the four preceding vertebræ, but the neural arch has been crushed downward so that the normal height of the spine has been somewhat reduced. Possibly this as well as the peculiar appearance of the postzygapophyses is due in part to antemortem causes. Both zygapophyses overhang the vertebral centrum. Of the latter, the anterior face is somewhat concave, which is also true, although in less degree, of the posterior one. The ventral groove is likewise increasing in depth. The chevron facets are well developed and coequal.

Measurements of Caudal XIX

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Length over all	355	360*	0.99
Height over all	290	490*	0.59
Width across diapophyses		145*	
Centrum, length	285	278*	1.02
" anterior face, height	170	210*	0.81
" " " width	215	193*	1.12
" posterior face, height	155	195*	0.79
" " " width	200	190*	1.05
" " " circumference		650*	
" mid length, width	126		
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			0.91

* Peterson's measurements.

Caudal XX.—This bone has been badly crushed, so that the anterior part is telescoped back upon the posterior, thus reducing very considerably the original length of the bone. There is little or no trace of pleurocœles nor is the hollow beneath the bone as pronounced as in XIX. The neural spine is lighter and the summit is distinctly smaller, which may indicate an original position still further back in the caudal series.

But few dimensions have value owing to the distortion of the bone.

Measurements of Caudal XX

	Barosaurus lentus mm.
Height over all	310
Centrum, posterior face, height	142
" " " width	183
" mid length, width	116

There are portions of centra which represent at least five more caudal vertebræ, one of which was anterior to the fourteenth and four posterior to the twentieth. In addition, there are two small distal bones, one of which is nearly perfect.

Caudal ca. XXXII (Pl. VI, Fig. 4).—The centrum of this bone is complete, as is the neural arch; the zygapophyses alone are lacking. The centrum is rather slender, with widely expanded ends, the posterior one of which is convex and oblique and possibly abnormal. The anterior face is somewhat concave. There is no trace of the inferior depression in the centrum nor of spinous process, although the latter may have been present above the missing postzygapophyses.

Measurements of Caudal ca. XXXII

	Barosaurus lentus mm.
Length over all	97
Height over all	52.5
Centrum, anterior face, height	37.8
" " " width	47
" posterior face, height	42.5
" " " width	37.5

Caudal ? .—A portion of the centrum of a distal caudal is preserved. It resembles those of the slender "whiplash" terminus of the tail of *Diplodocus,* as there is no trace whatever of the neural arch. The fragment seems to pertain to the posterior half of the original bone, as the articular face is convex.

Measurements of Caudal ?

	Barosaurus lentus mm.
Length as preserved	5.5
Articular face, height	21.7
" " width	22.7
Centrum, height	17.3
" width	11.6

CHEVRON BONES

Of the bones which constitute the hæmal arch of the tail, the chevrons, three characteristic ones are present, illustrating two distinct types.

Chevron ca. V (Pl. VI, Fig. 5; Text Fig. 3).—One of these chevrons is from the anterior part of the tail. In size it compares with the fifth in the American Museum specimen of *Diplodocus longus,*[5] and agrees therewith in curvature, although somewhat more tapering. The base is broad, complete, and the two sides are connected by a

[5] Osborn, op. cit., Fig. 12.

transverse bar of bone. The hæmal canal is triangular and extends a little more than one-sixth the length of the bone. The bone is laterally compressed, dagger-like, with rather acute front and rear margins, especially in the distal third of the front and half of the rear edge. The articular facet is continued down the posterior side as though there had been considerable backward inclination of the bone.

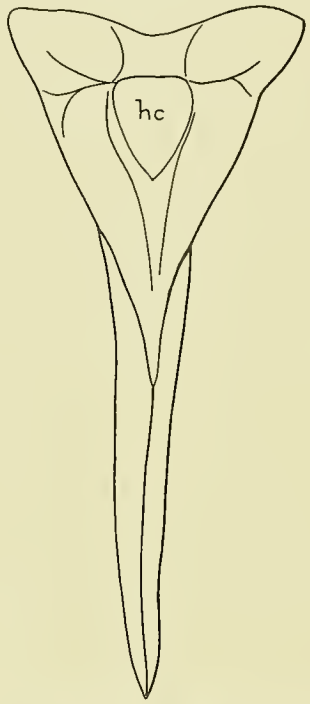


FIGURE 3.—Chevron V, rear aspect. One-fourth natural size. Note the slight asymmetry. hc, hæmal canal.

Measurements of Chevron ca. V

	Barosaurus lentus mm.
Length	348
Width of base	155.7
Width of mid length	36
Antero-posterior diameter of blade	63
Hæmal canal, height	55
" " width	39

Chevron ca. IX (Pl. VI, Fig. 6; Text Fig. 4).—A second chevron is present which can not have been far from the ninth. The bearing surface is nearly as broad as before, the hæmal canal larger, but the blade of the chevron is materially shorter. The last seems to be pathologic, as there is a foramen (see Pl. VI, Fig. 6, f) passing through the blade below and at right angles to the hæmal canal. This aperture is a longitudinal slit-like perforation with rounded margins, penetrating not the main mass of the bone but the two ridges which continue downward on either side of the hæmal canal on the posterior margin of the bone. This ridge is broken away on the left side of the bone, but is complete on the right. Whether there were two foramina, or

whether the two ridges had coalesced to form a single roofing is not quite clear. The latter, however, I believe to have been the case. Viewed from either side, the perforations are quite symmetrical. I have no idea as to the cause of this seemingly unique phenomenon. The entire bone, viewed from either front or rear, is curiously asymmetrical, as were the vertebræ. (See Text Fig. 4.)

Measurements of Chevron ca. IX

	Barosaurus lentus mm.
Length	243
Width of base	136.7
Antero-posterior diameter of blade	55.5
Hæmal canal, height	67
" " width	44

Chevron ca. XVI (Pl. VI, Fig. 7; Text Fig. 5).—A third chevron is present, admirably preserved except for the extreme anterior point. This bone is elongated in its antero-posterior diameter and hence presents a very different appearance from those

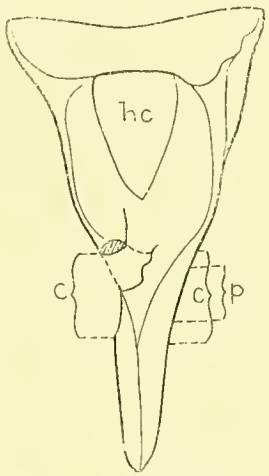


FIGURE 4.—Chevron ca. IX, rear aspect. One-fourth natural size. Note the decided asymmetry. hc, hæmal canal; c, crease; p, perforation, see text.

which have been described. It differs in shape, moreover, from any of those preserved with the American Museum specimen (*vide supra,* preface) in that the ascending portion is proportionately somewhat heavier than the fore and aft extensions.

The base is heavy, with large facets, of which the lesser forward area is perhaps three-fifths as great as the posterior.

The bone shows little asymmetry as contrasted with that just described (compare Pl. VI, Figs. 6 and 7). The margin of the posterior extension rises in a gentle curve into that of the base; the anterior margin, on the other hand, is much more abruptly curved, as the figure shows. Ventrally, there is an elongated, alveolus-like depression (Text Fig. 5 B, a), forerunner of the median opening which, in the more posterior chevrons of *Diplodocus,*[6] separates the bone into a pair of slender rods. This alveolus-like

[6] Osborn, op. cit., p. 209.

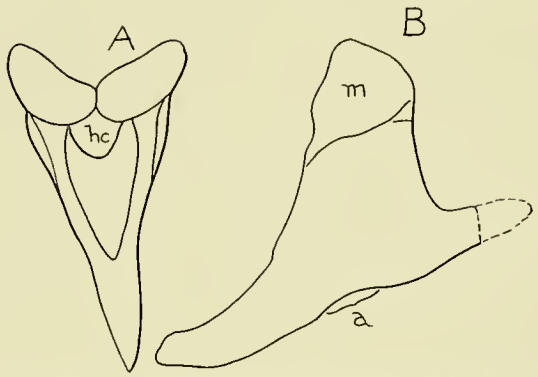


FIGURE 5.—Chevron ca. XVI. A, rear, B, right lateral aspect. One-fourth natural size. hc, hæmal canal; m, muscle area; a, alveolus.

depression seems to be in no way homologous with the perforation mentioned in chevron IX.

There is on either side a distinct muscle area (Text Fig. 5 B, m) on the proximal portion of the chevron, bounded by a pronounced horizontal ridge. This is not apparent on either of the two chevrons which have been described. The chevron of *Diplodocus longus* type (Yale Mus. No. 1920), which is shown on Plate VI, Fig. 8, represents but one half of the bone under consideration, as the cleavage into two elements is here complete. There is, however, a facet at the posterior end only for contact with the other element of the pair (see also Text Fig. 6).

Measurements of Chevron ca. XVI

	Barosaurus lentus mm.
Perpendicular length	120
Width of base	93
Horizontal length as preserved	181.5
Hæmal canal, height	14
" " width	25
Alveolus, antero-posterior diameter	20
" transverse diameter	5
" depth	18

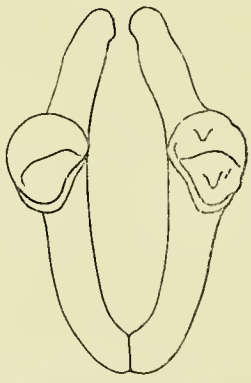


FIGURE 6.—Chevrons of *Diplodocus longus,* inferior aspect, after Marsh. One-fourth natural size. Compare Figure 4.

RIBS

A number of ribs, both cervical and dorsal, are present. They are large, but in their present condition show little distinction from those of *Diplodocus* or *Brontosaurus*. None of the dorsal ribs is sufficiently complete to indicate the size of the chest cavity, which would be a point of considerable interest.

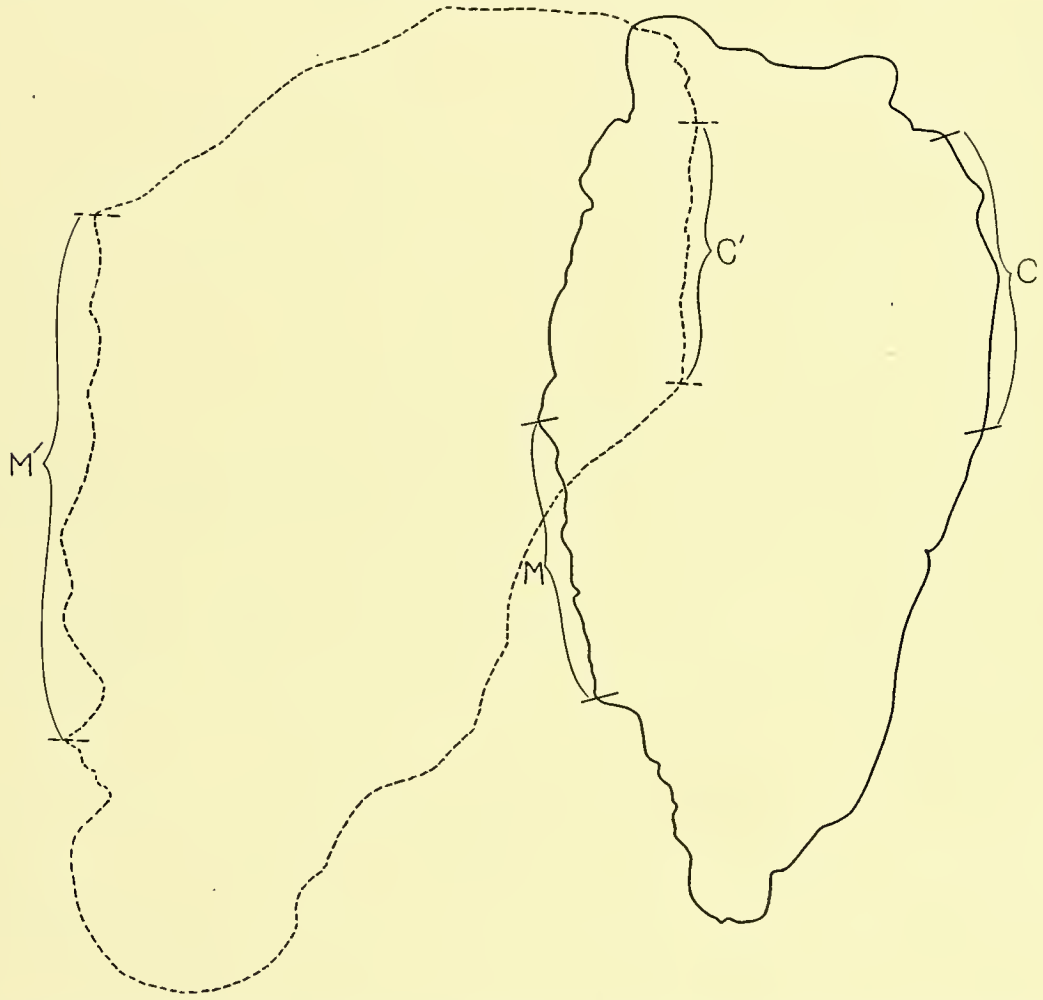


FIGURE 7.—Sternals of *Barosaurus* and *Diplodocus carnegiei*. One-fourth natural size. Entire outline, *Barosaurus;* dotted outline, *Diplodocus,* drawn from the photograph by Hatcher 1901, Figure 12. C, C', coracoid articulation; M, M', median articulation.

STERNAL

This bone (Pl. VI, Fig. 1; Text Fig. 7) is in splendid condition except that its posterior end is somewhat eroded. It is an oval plate, one surface of which, the visceral, is concave, the other convex. The margin is somewhat irregular, but two articular areas are distinctly visible, one for its fellow on the inner margin, the other on the exterior border near the anterior end for the coracoid. The latter particularly

shows an increased thickness and rugosity, as though continued somewhat in cartilage. Areas for muscle attachment are also visible around the margin, especially toward the posterior end on the outer side. The general thickness of the bone is more or less uniform, rarely exceeding 19 mm. at mid length to 12 mm. toward the anterior end. The knob-like posterior end, on the other hand, is 68 mm. thick. The outline drawn to scale with that of *Diplodocus carnegici* is here shown (Text Fig. 7).[7] Were the posterior portion of the *Barosaurus* sternal intact, its length would more nearly equal that of *D. carnegiei.*

Measurements of the Sternal

	Barosaurus lentus mm.	*Diplodocus carnegici**	*Ratios*
Antero-posterior diameter	485†	540	0.90
Greatest transverse diameter	250	310	0.80
Length, median articulation	150	280	0.70
Length, coracoid articulation	160	140	1.14
Index, length to breadth	1.92 : 1	1.74 : 1	

* From Holland's figure.
† As preserved.

Appendicular Skeleton

fore limb and girdle

The only portion of the fore limb or its girdle present is a fragment which has been identified as of a scapula, largely through a process of elimination, as the outline is only in very small part preserved.

Scapula (see Pl. VII).—This bone consists of a portion 810 mm. long by 22.5 mm. wide. But two portions of the outline remain, one somewhat irregular at the distal end, and a small portion of the almost straight lateral border. The bone is fairly massive, thinning toward the margin, but in no way remarkable, judging from the very inadequate portion preserved.

hind limb and girdle

The hinder extremities are represented by a number of elements, none of which unfortunately is complete.

Ilium (see Pl. VII).—Of the ilium there are present a number of marginal fragments, including a portion of the acetabulum and the pubic peduncle. Further description, however, is of little value.

Pubis (Pl. VI, Fig. 2; Text Fig. 8).—A right pubis is present, excellently preserved except for its distal end, of which a considerable portion is missing. A portion of the proximal end is also eroded away, but this is relatively inconsiderable. A scale drawing has been made superposed upon that of *Diplodocus carnegiei* enlarged from Hatcher's figure (op. cit. Pl. I, Fig. 1). The pubis of *Barosaurus* was the larger, although the preserved portion is actually the shorter of the two. The ratio of shaft widths, about the only absolute measurement, is essentially that of the femora and tibiæ, about 1.70, actually 1.69. Were the same ratio maintained in the relative lengths, that of *Barosaurus*

[7] W. J. Holland, The Osteology of Diplodocus Marsh. Mem. Carnegie Mus., Vol. 2, No. 6, 1906, Figs. 25, 26.

would be 1,385 mm. A conservative estimate of at least a metre seems safe. (See also Pl. VII.)

Compared with the pubis of *Apatosaurus,* that of *Barosaurus* is much lighter; it is in every way, except for its greater size, much more like that of *Diplodocus.* The proximal end is heavy, the pubic foramen oval, of good size, and running obliquely

FIGURE 8.—Pubis of *Barosaurus* and *Diplodocus carnegiei,* superimposed. One-sixth natural size. Entire outline, *Barosaurus;* dotted outline, *Diplodocus,* from a photograph by Hatcher 1901, Plate X, Figure I. A, A', ischiatic articulation.

through the bone not far from its present posterior border. Below this thin, incomplete margin, there is a rugose articular surface which formed the ischiatic articulation. Externally, the bone has a fine curve, with a completely preserved rounded margin, which, except for the rugosity mentioned above, is thicker than that on the inner side of the bone. The visceral aspect is concave, the external one generally convex, as in the sternal.

Measurements of the Pubis

	Barosaurus lentus mm.	*Diplodocus carnegici* mm.	*Ratios*
Length ..... preserved	665	820	1.69
Length ..... estimated	1385		
Length, iliac articulation		240	
Length, ischiatic articulation	290	180	1.61
Width, proximal end (present)	390	365	(1.07)–
Width, shaft	177	105	1.69
Width, distal end .....estimated ca.	400	240	1.69
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			1.67

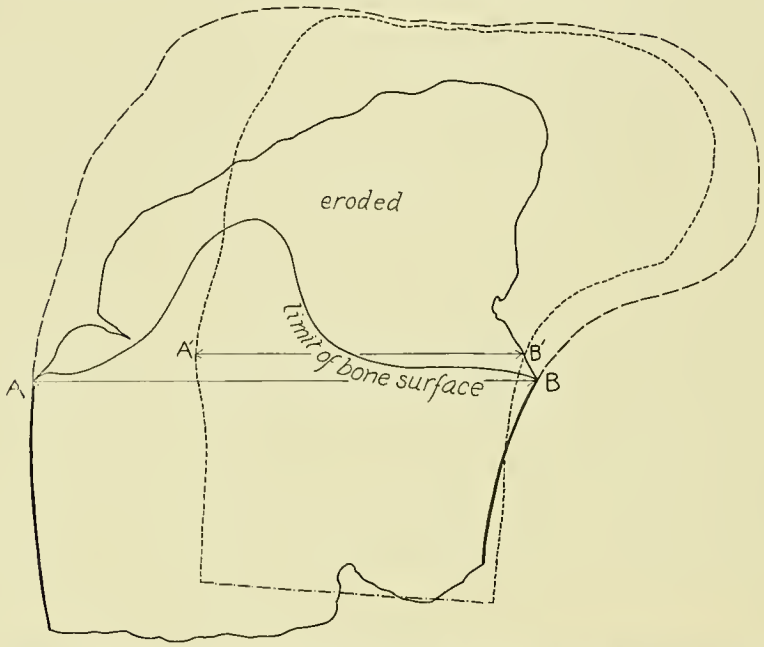


FIGURE 9.—Femur of *Barosaurus* and *Diplodocus carnegiei,* proximal ends superimposed. One-sixth natural size. Entire outline, *Barosaurus,* the summit of which is eroded away, dashes indicating the probable outline; dotted line, *Diplodocus,* from a photograph by Hatcher 1901, Plate XI, Figure 3. A B, A′ B′, dimensions recorded in text, page 37.

Ischium (see Pl. VII).—What appears to be the proximal end of the left ischium is present. The acetabular surface is complete, slightly roughened, and thin-edged, very much as in *Diplodocus.* The *Barosaurus* ischium is larger, but a ratio between the bones is impossible to ascertain, except that the chordal distance across the acetabular surface is about 280 mm. to 250 mm. for *D. carnegici,* a ratio of 1.12 : 1.

If one may judge of the direction of the grain of the bone, the ischium of *Barosaurus* does not seem to have had so slender a shaft as in *Diplodocus,* but this is highly conjectural. There is also a small portion of what seems to be the distal part of the ischium present, if the identity of the bone be correctly determined. It resembles that of *Apatosaurus* more than *Diplodocus,* in being more squarely truncated distally, and in having a rather prominent ridge on the outer face.

Femur (Pl. VII; Text Fig. 9).—A number of fragments of a femur are present. Of these, three have been assembled to form the proximal end. This gives a clue to the enormous proportions of the bone, which are about one and three-quarters those of *Diplodocus* as estimated from Hatcher's figures (op. cit., Figs. 15-17). The same relative dimensions are true also of the distal end of the tibia, which is likewise preserved. A sketch of the relative proportions is here shown (Text Fig. 9). The measurements as thus indicated follow:

Measurements of the Femur

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Diameter at AB, transverse	395	230	1.72
Diameter at AB, thickness	170*	137.5	1.23+
Circumference at AB	950		
Length	(?2525.8)	1468.5	(1.72)
Average ratios: *Barosaurus lentus* and *Diplodocus carnegiei*			1.47

* Crushed.

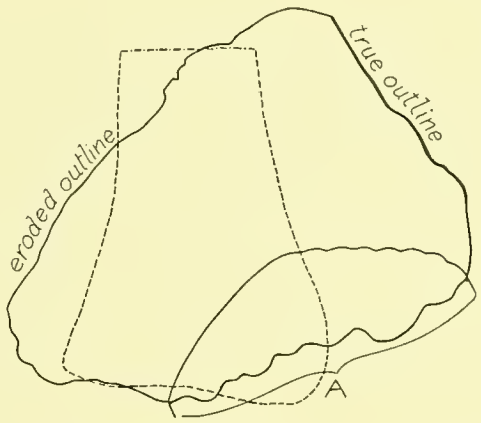


FIGURE 10.—Tibia of *Barosaurus* and *Diplodocus carnegiei,* distal ends superimposed. One-sixth natural size. Solid line, *Barosaurus;* dotted line, *Diplodocus,* from the photograph by Hatcher 1901, Plate XI, Figure 1. A, astragalar facet.

This immense length, 8 feet 2½ inches, is manifestly improbable, but is about what the length would be were the known ratios with *Diplodocus* carried out. The near approximation of lengths of the dorsal and caudal vertebræ in the two genera would lead one to infer a similar correspondence in the femoral length, despite the greatly enlarged cervicals in *Barosaurus,* the latter implying possibly elongated fore limbs as in *Brachiosaurus,* not hind limbs as well.

The distal end of a femur, probably the left, is also present. Although only its anterior face is preserved intact, the inner condyle is indicated and also the beginning of the outer. The proportions which may thus be ascertained would make it about 350 mm. across as compared with about 250 for *D. carnegiei,* giving a ratio of about 1.40, less than that of the proximal end. These measurements are, however, inaccurate

owing to the faulty preservation of the *Barosaurus* bone. A number of good-sized fragments of the femoral shaft are present, but from lack of contacts they give no clue to the length of the bone.

Tibia (Text Fig. 10).—The distal end of the right tibia is present, as are other fragments doubtless referable thereunto but not recognizable. The articular end is very rugose and deeply concave in the astragalar facet. The articular extremity is widely expanded, as compared with the shaft, although this appearance is heightened by the corrosion of the inner (median) side above the articular facet. What appears to be part of the proximal end of the tibia is also present, but affords no significant measurements. Those of the distal end follow:

Measurements of the Tibia

	Barosaurus lentus mm.	*Diplodocus carnegiei* mm.	*Ratios*
Distal end, transverse diameter	380	212	1.787
" " antero-posterior diameter	220		
" " circumference	980		
Length	(?1680.7)	940.5	1.787

Here again the tibial ratio is so very great that were it carried out in the length, that of *Barosaurus* would be about 5 feet 6 inches, or 13 feet 8½ inches for the femur and tibia alone, exclusive of the foot.

Fibula.—The two ends of the fibula are also present, and again the intervening bone is not preserved. The proximal portion has a very distinct muscle insertion on its anterior face.

The distal end of the fibula is but a fragment, and is highly rugose on its articular end, as is the tibia. Available measurements are of little value, but indicate a ratio with those of *Diplodocus* approximating those of femur and tibia.

BAROSAURUS AFFINIS

Of the material found in the *Barosaurus* quarry, there are but three fossils, two foot bones and one tooth, which do not seem to pertain to the type specimen of *B. lentus*. It will be remembered that all of Marsh's description of the second species was contained in the single sentence, "With these fossils were found remains of a much smaller species which may be called *Barosaurus affinis.*" There is absolutely no indication of what these remains were, nor are any of the bones labeled or otherwise distinguished as of another species. The tooth, which is that of a carnivorous dinosaur, can not belong to the species of sauropod under discussion, and this leaves only the two foot bones as possibly those to which Professor Marsh referred.

These, which are metacarpals I and II of the left manus, are of the approximate size of those of *Morosaurus grandis* Marsh, type specimen No. 1905, Yale Museum. They are, on the other hand, much smaller than the equivalent bones of *Diplodocus longus* type, as the ratios in the table of measurements show. From these ratios it

seems conclusive that they could not have belonged to the type of *Barosaurus lentus,* whose measurements, as we have seen, are rarely smaller than those of *Diplodocus,* and in the forward part of the skeleton as preserved largely exceed it. *D. longus* and *D. carnegiei* are approximately of a size, nor is it clear that they are specifically distinct.

Metacarpal I (Pl. VI, Fig. 9).—This bone is absolutely perfect, and while slightly fissured, has been naturally cemented so that no repair was necessary. In form it resembles that of *Morosaurus lentus* very closely, the likeness being much greater than to *Diplodocus longus.* The main distinction from *Morosaurus* lies in the outer and distal aspects, the latter being wider transversely and of less antero-posterior extent, while the outer posterior angle is prolonged outward. The articular face in *Morosaurus* therefore is roughly rectangular, although with an inwardly curved posterior border, while in *Barosaurus* the outer and inner sides form an angle of nearly 45 degrees with each other. This of course renders the form of the outer surface somewhat different as well.

Metacarpal II (Pl. VI, Fig. 10).—This is only partly preserved, as the distal half is gone. In size it once more approximates that of *Morosaurus lentus,* but differs in that the proximal articular face is more rugose, as though it bore a relatively somewhat thicker articular cartilage. The surface of the bone in *Barosaurus* is almost convoluted, in *Morosaurus* pitted. There is a similar distinction in the equivalent surfaces of metacarpal I, but it is somewhat less marked in the former. In *Barosaurus* the shaft is much more irregular in section, with one acute angle, while in *Morosaurus* it is again roughly rectangular.

Measurements of the Metacarpals

	Barosaurus affinis mm.	*Morosaurus lentus* mm.	*Diplodocus longus* mm.
Metacarpal I			
Length	138	137	209*
Proximal face, transverse diameter	86	92	146
" " anterior-posterior diameter	105	106†	148
Distal face, transverse diameter	120	105	152
" " anterior-posterior diameter	69	76	105
Width of shaft (least)	80	79	108
Metacarpal II			
Length		179	
Proximal face, transverse diameter	97	96	
" " anterior-posterior diameter	98	112	

* From Marsh's figure.

† Slightly restored.

THEROPOD DINOSAUR GEN. ET SP. INDET.

A single tooth of a carnivorous dinosaur (Yale Museum Cat. No. 415) was present in the quarry in association with the *Barosaurus* skeleton (see Fig. 2, 16). It is lightly constructed, sharply curved, and a portion of the hollow base filled with matrix is preserved. Serrations on the anterior convex border can hardly be seen with the naked eye but are nevertheless discernible for nearly half the preserved length from the tip. On the after concave border they are more pronounced but still minute, and extend for the entire present length of the tooth.

While this tooth has not with certainty been identified, it is comparable in size and curvature to certain ones in the after portion of the maxillary of the *Allosaurus fragilis* skull preserved in the American Museum of Natural History, but this is rather slender evidence upon which to base an identification of so generalized a tooth. The dimensions are:

	mm.
Total length preserved	26
Antero-posterior diameter at base	10.7
Transverse diameter at base	4.7

RELATIONSHIPS

Comparison with Diplodocus.—It is evident that *Barosaurus lentus* represents a highly specialized sauropod dinosaur, ponderous of limb, the relative proportions of which unfortunately can not be ascertained from the single known specimen. The preserved elements compare most nearly with those of *Diplodocus,* but differ remarkably in certain proportions. These resemblances may have been in part convergent and merely similar mechanical adjustments of bony tissue to meet similarly disposed strains and stresses, and as such imply no close relationship. Among the points of agreement are the general proportions of the vertebræ, although as one goes toward the tail the relative height of the neural spines grows less in *Barosaurus.* Pleurocœles are similar in disposition and their proportions are somewhat alike. The caudals of both *Barosaurus* and *Diplodocus* are also alike in having a concavity in the ventral surface of the centrum. There is also a general similarity of the chevrons and of the arrangement of the laminæ of the vertebra throughout the series. Indeed, two of the distinctive features of *Diplodocus* as set forth in Marsh's original description are the presence of the excavation on the ventral surface of the caudal centra and the two-branched character of the chevrons, upon which the name *Diplodocus* (διπλόος, double, + δοκός, rafter) is founded and which Marsh says distinguishes the vertebral column from that of all other Sauropoda. These do not, however, serve to distinguish *Diplodocus* from *Barosaurus.* The third point, the elongated caudals in the former, is a distinction.

The main general differences between *Barosaurus* and *Diplodocus* may be summarized as follows: Details of the lamina of the vertebra, simple character of the

neural spines of the after dorsals in *Barosaurus,* and position of the capitular facet on the dorsal vertebra, which rises more rapidly in *Diplodocus.* The other marked distinctions are those of proportions, for while the dorsal series of vertebræ as a whole approximate in length in the two animals, that of *Barosaurus* being only slightly the longer, the cervicals in the latter are vastly greater and the caudals markedly less. The relatively lower height of the spines of the after vertebræ is correlated with the more abbreviated tail. The weight of the hind limbs is more like that of *Brontosaurus* than of *Diplodocus carnegiei.* Of their length and the character of the fore limbs we have no data. The obliquity of the centrum faces of the posterior cervicals and first dorsal of *Barosaurus* seems to imply a different carriage of neck, probably giraffe-like as in the Tendaguru *"Brachiosaurus"* as restored by Matthew. If so, it would perhaps also imply elongated fore limbs like those of *Brachiosaurus.*

Comparison with Brontosaurus.—With *Brontosaurus,* the general mechanical resemblances also hold; this applies to the character of the neural spines, but the huge proportions of the cervicals in *Barosaurus* are a distinction, as is also the more *Diplodocus*-like character of the caudals.

Comparison with Brachiosaurus.—Compared with the American *Brachiosaurus* of Riggs[8] and the smaller related form, *Haplocanthosaurus* Hatcher,[9] I find no points of resemblance in any known element. The following characters are given by Riggs for the family Brachiosauridæ, especially *Brachiosaurus* itself: (1) Humerus as long as femur. In *Barosaurus* the humerus is unknown. (2) Neural spines of vertebræ simple. In *Brachiosaurus* those of more than half of the dorsal series are deeply bifid. (3) In *Brachiosaurus* the zygapophyses reach extreme reduction and the hyposphene-hypantrum articulation reaches extreme development. In *Barosaurus* the zygapophyses are well developed and also the latter articulation, but there is nothing extreme about it. (4) Riggs also emphasizes the low, broad structure of the vertebral pedicels. This perhaps may also be said of *Barosaurus* to a certain extent. (5) The dorsal pleurocœles in *Brachiosaurus* are much longer than high, the length being between two and two and a half times the height, whereas in *Barosaurus* they are as high as or higher than long. (6) The laminæ are not so pronounced in *Brachiosaurus* as in *Barosaurus,* and the neural spines of the dorsal vertebræ and probably of the sacrum are relatively lower in *Brachiosaurus.*

Altogether, I see no indication of relationship with the Brachiosauridæ.

Comparison with "Brachiosaurus" of Tendaguru.—The description of the Tendaguru species, *"Brachiosaurus" brancai,* which we possess is unfortunately very meagre.[10] The figured cervical (Fig. 1), which is spoken of as lying in the "second quarter," that is, between the sixth and ninth, is quite similar to those of *Barosaurus* in many details, the principal distinction being the overhanging prezygapophyses which increase the over-all length markedly beyond that of a *Barosaurus* cervical, the centrum of which

[8] E. S. Riggs, *Brachiosaurus altithorax,* the largest known Dinosaur. Amer. Jour. Sci., 4th ser., Vol. 15, 1903. pp. 299-306, 7 figs.

[9] J. B. Hatcher, Osteology of *Haplocanthosaurus.* Mem. Carnegie Mus., Vol. 2, 1903, pp. 1-72, 6 pls., 28 figs.

[10] W. Janensch, Uebersicht ueber der Wirbeltierfauna der Tendaguru-Schichten. Archiv f. Biontologie, Berlin, III. Bd., 1. Heft, 1. Teil, 1914, pp. 82-83, 86-98, Figs. 1-6.

may actually have been longer. The *"Brachiosaurus"* bone in question naturally most nearly resembles cervical XII, that is, the anterior one of *Barosaurus* which is preserved, and doubtless had we the identical element, the resemblance would be yet closer. From cervical XII it differs in the relatively slenderer centrum and longer pleurocœle, but the other differences, except the overhanging prezygapophyses, are largely those of detail, as the main laminæ and other structural features are not unlike.

Conclusions.—Unless the German author, Janensch, actually made a comparison of the dorsals of the Tendaguru genus with those of the American *Brachiosaurus* and found sufficient agreement, I see no reason for including the African form in this genus merely on the ground of the elongated fore limbs, as we have no reason to know that *Brachiosaurus* had huge cervical vertebræ. Certainly those of the related *Haplocanthosaurus* were not, but on the contrary were relatively short. The unpaired neural spine is characteristic of the Brachiosauridæ, but not of *Brontosaurus, Morosaurus, Diplodocus, Barosaurus,* nor so far as I know of the African genus. Whether *Barosaurus* possessed an elongated fore limb we do not know, but there is certainly no evidence against it. Hence from the evidence before me, the huge cervicals of the African form, which resemble so much those of *Barosaurus* rather than the known cervicals of the Brachiosauridæ, specifically *Haplocanthosaurus*. seem to show that the comparison lies with *Barosaurus* rather than with *Brachiosaurus,* especially as there is no present evidence to the contrary. Further evidence from Berlin, if such were available, might serve, in the light of the present study of *Barosaurus,* to clarify the relationships.

The comparison with other Sauropoda may be expressed in tabular form as follows:

	Cervicals	Anterior dorsal spines	Tail	Fore limbs
Barosaurus	Huge	Paired	Moderately short	Unknown Great size inferred
Brachiosaurus	Unknown	Unpaired	Unknown, except two anterior vertebræ	As long as hind limbs
Haplocanthosaurus (Least specialized)	Short	Unpaired, short and simple throughout column	Very short	Unknown
Brontosaurus	Moderate	Paired	Very long	Smaller than hind
Diplodocus	Moderate	Paired	Very long	Smaller than hind
Tendaguru genus	Huge	Unknown[11]	Very short	As long as hind limbs

[11] One dorsal only was in part prepared for study in 1914. This has an unpaired spine, but as its position in the series is unknown, no significance can be attached to the character of the spine, since the spines are unpaired in the posterior dorsals of all Sauropoda.

PLATE I. Photograph of excavation for *Barosaurus lentus* Marsh at Piedmont, South Dakota, October 2, 1895. Looking southeast to east. Showing group of vertebræ N, O, P, and Q, with cervical T marked by large pick, and point of further excavation by small hand pick. Photograph by G. R. Wieland, *American Fossil Cycads,* Plate L, photograph 2. Courtesy of Doctor Wieland.

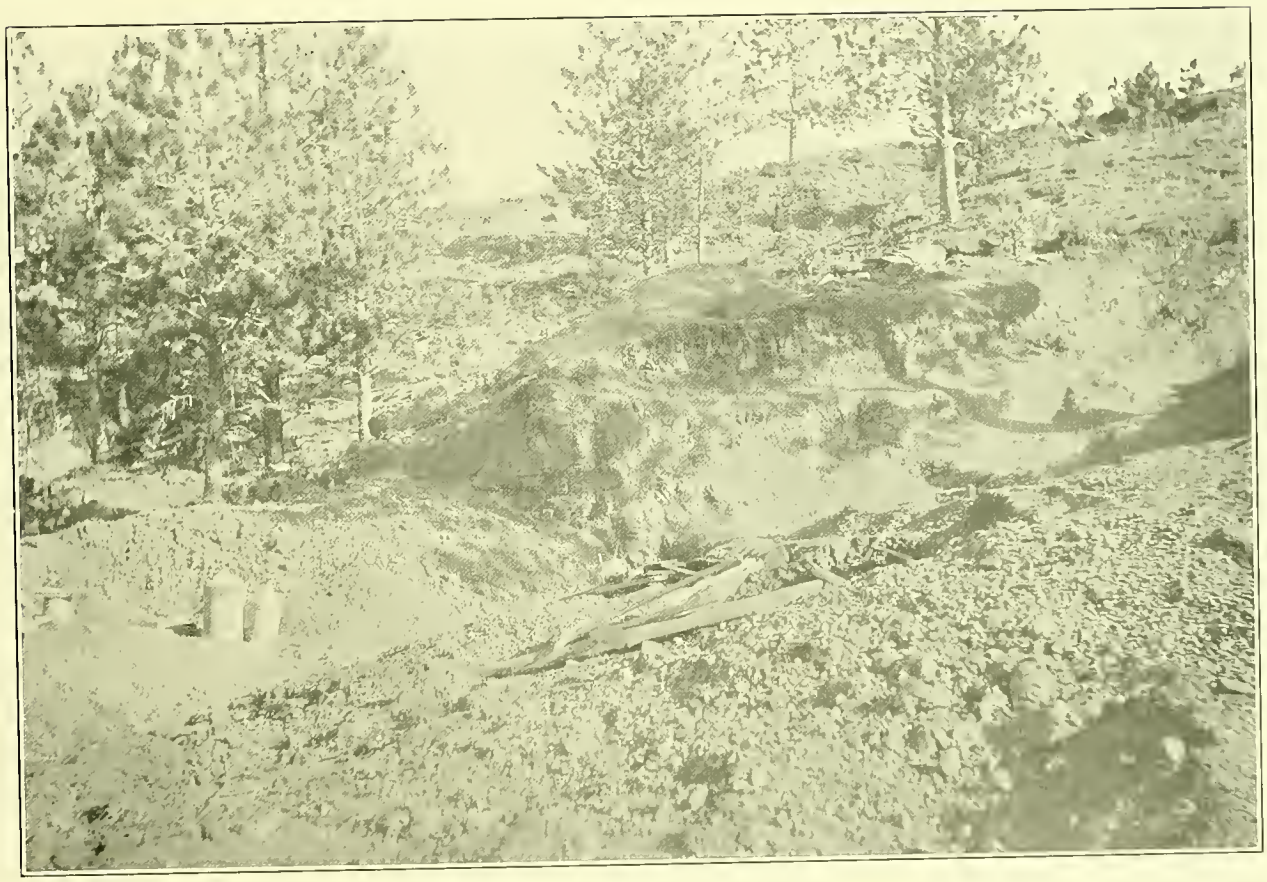


PLATE II. Cervical vertebræ of *Barosaurus*.

Figure 1. Cervical XII (Vertebra S), right lateral aspect. One-tenth natural size.

Figure 2. Cervical XIII (Vertebra Q), oblique ventral aspect. One-tenth natural size.

Figure 3. Cervical XV (Vertebra R), dorsal aspect. One-tenth natural size.

Figure 4. Cervical XV (Vertebra R), ventral aspect. About one-eighth natural size.

Key drawing: A, anterior, P, posterior face of centrum. CAP.FAC., capitular rib facet; DIAP., diapophysis; HOR.LAM., horizontal lamina; N.SP., neural spine; P.L., pleurocœle; PC.L., pleurocœle lamina; P.Z., postzygapophysis; POST.OB., posterior oblique lamina; PR.Z., prezygapophysis; TUB.FAC., tubercular facet; W.E., wing-like expansion.

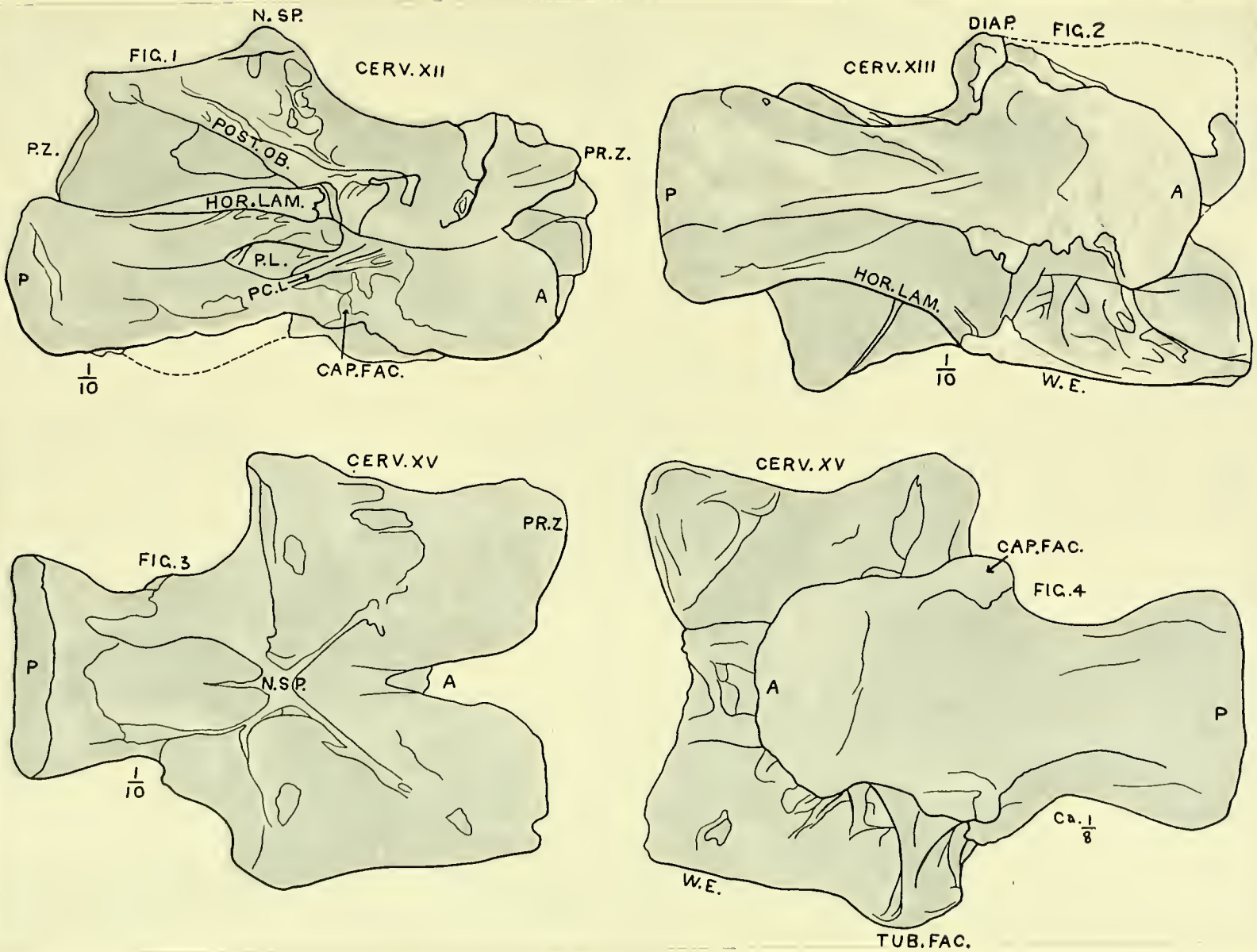


FIG. 1
N. SP.
CERV. XII
POST. OB.
P.Z.
PR.Z.
HOR. LAM.
P.L.
PC.L.
P
A
CAP. FAC.
1/10
FIG. 2
DIAP.
CERV. XIII
P
A
HOR. LAM.
1/10
W. E.
FIG. 3
CERV. XV
PR.Z
P
N.S.P.
A
1/10
CERV. XV
CAP. FAC.
FIG. 4
A
P
Ca. 1/8
W. E.
TUB. FAC.

FIG. 1
N. SP.
CER. V. XII
CAV. GAS.
PR. 2
PR. 1
HOR. PROC.
POST. PROC.
M. E.
FIG. 2
SPH.
CER. V. IX
PR. 2
FIG. 3
M. E.
CAV. BUT.
CAV. GAS.
FIG. 4
CER. V. X

PLATE III. Dorsal vertebræ of *Barosaurus*. One-eighth natural size.

Figure 1. Dorsal I (Vertebra P), anterior aspect.

Figure 2. Dorsal I (Vertebra P), posterior aspect.

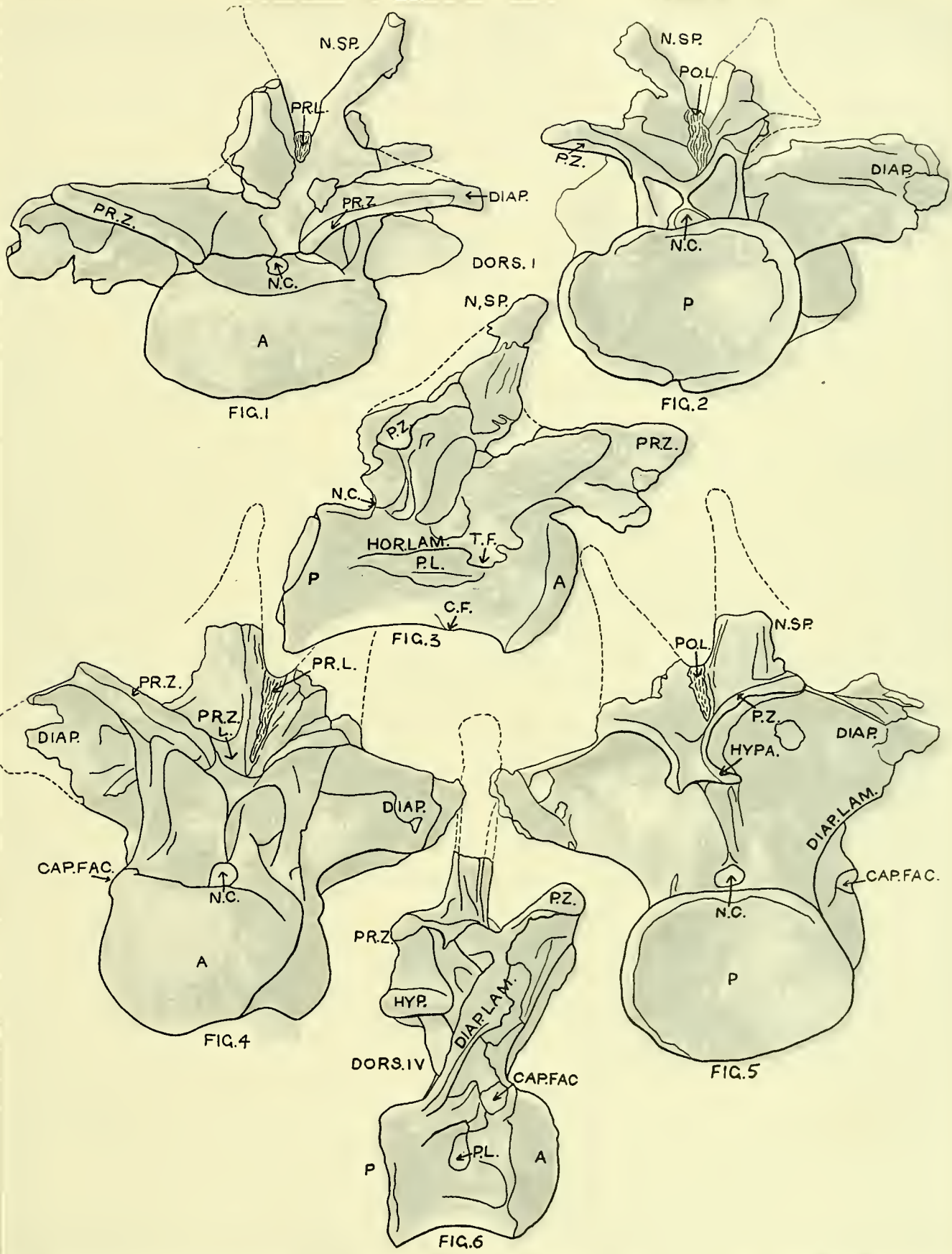
Figure 3. Dorsal I (Vertebra P), right lateral aspect.

Figure 4. Dorsal IV (Vertebra H), anterior aspect.

Figure 5. Dorsal IV (Vertebra H), posterior aspect.

Figure 6. Dorsal IV (Vertebra H), right lateral aspect.

Key drawing: A, anterior, P, posterior face of centrum. C.F. or CAP.FAC., capitular rib facet; DIAP., diapophysis; DIAP.LAM., diapophysial lamina; HOR.LAM., horizontal lamina; HYPA., hypantrum; N.C., neural canal; N.SP., neural spine; P.Z., postzygapophysis; P.L., pleurocœle; PO.L., postspinal lamina; PR.L., prespinal lamina; PR.Z., prezygapophysis; PR.Z.L., prezygapophysial lamina; T.F., tubercular rib facet.


N.SP.
PR.L.
PR.Z.
DIAP.
PR.Z.
N.C.
DORS. I
A
FIG. 1
N.SP.
PO.L.
P.Z.
DIAP.
N.C.
P
FIG. 2
N.SP.
P.Z.
PR.Z.
N.C.
HOR.LAM.
T.F.
P.L.
P
A
C.F.
FIG. 3
PR.Z.
PR.L.
PR.Z.
L.
DIAP.
DIAP.
CAP.FAC.
N.C.
A
FIG. 4
PO.L.
N.SP.
P.Z.
DIAP.
HYPA.
DIAP.LAM.
CAP.FAC.
N.C.
P
FIG. 5
P.Z.
PR.Z.
HYP.
DIAP.LAM.
DORS. IV
CAP.FAC
P.L.
P
A
FIG. 6

N.SP.
POL.
DIAP.
PR.Z.
N.C.
P
FIG.2
N.SP.
PRL.
DIAP.
PR.Z.
PR.Z.
N.C.
DORS.I
A
FIG.1
N.SP.
PR.Z.
PR.Z.
N.C.
HORI.LAM.
T.F.
PL.
A
P
C.F.
FIG.3
N.SP.
POL.
PR.L.
PR.Z.
PR.Z.
DIAP.
HYPA.
DIAP.
DIAP.L.AM.
CAP.FAC.
N.C.
N.C.
P
FIG.5
P.Z.
PR.Z.
HYP.
DIAP.LAM.
DORS.IV
CAP.FAC.
A
PL.
P
FIG.6
CAP.FAC.
A
FIG.4

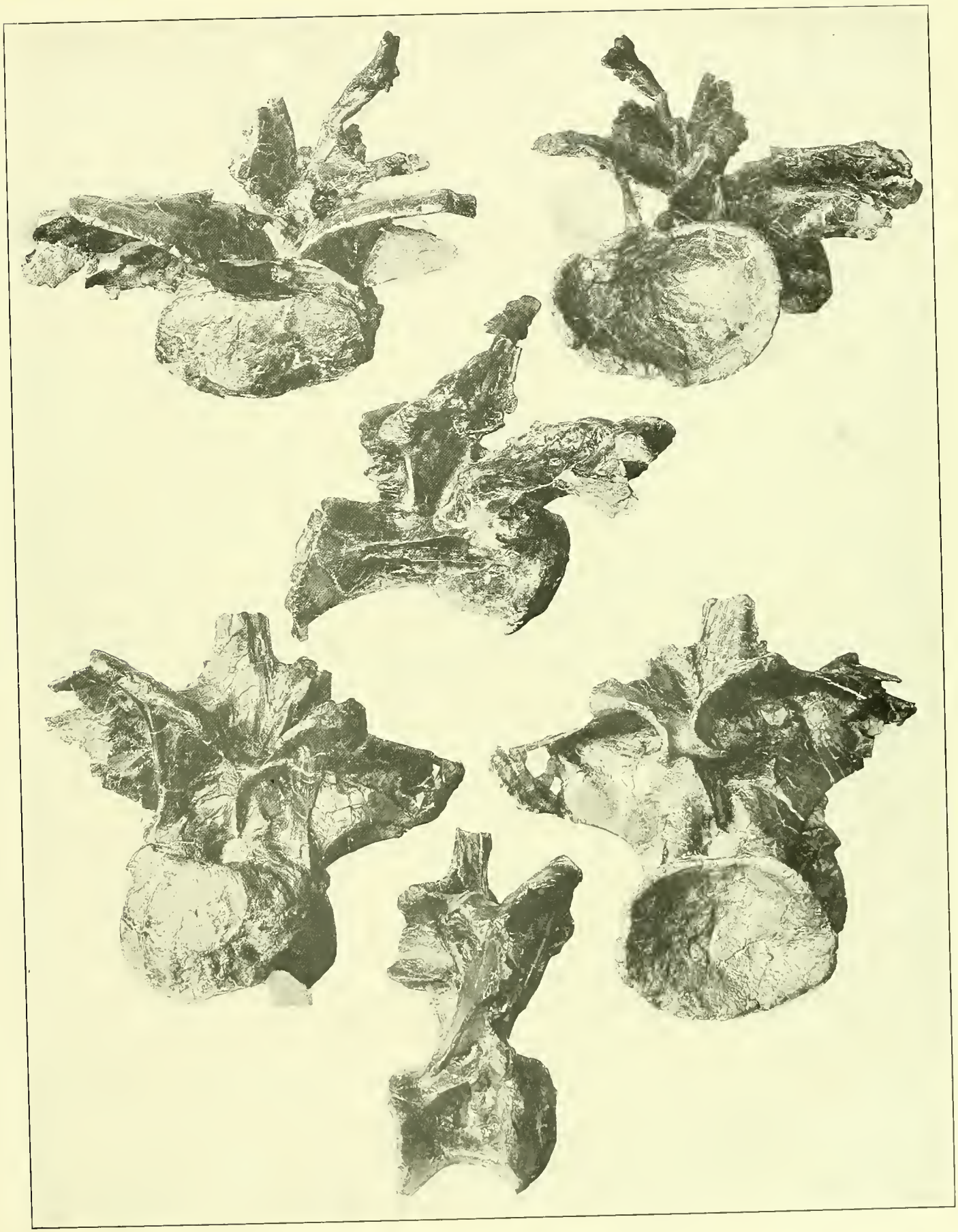


PLATE IV. Dorsal vertebræ of *Barosaurus*. About one-eighth natural size.

Figure 1. Dorsal V (Vertebra L), anterior aspect.

Figure 2. Dorsal V (Vertebra L), right lateral aspect.

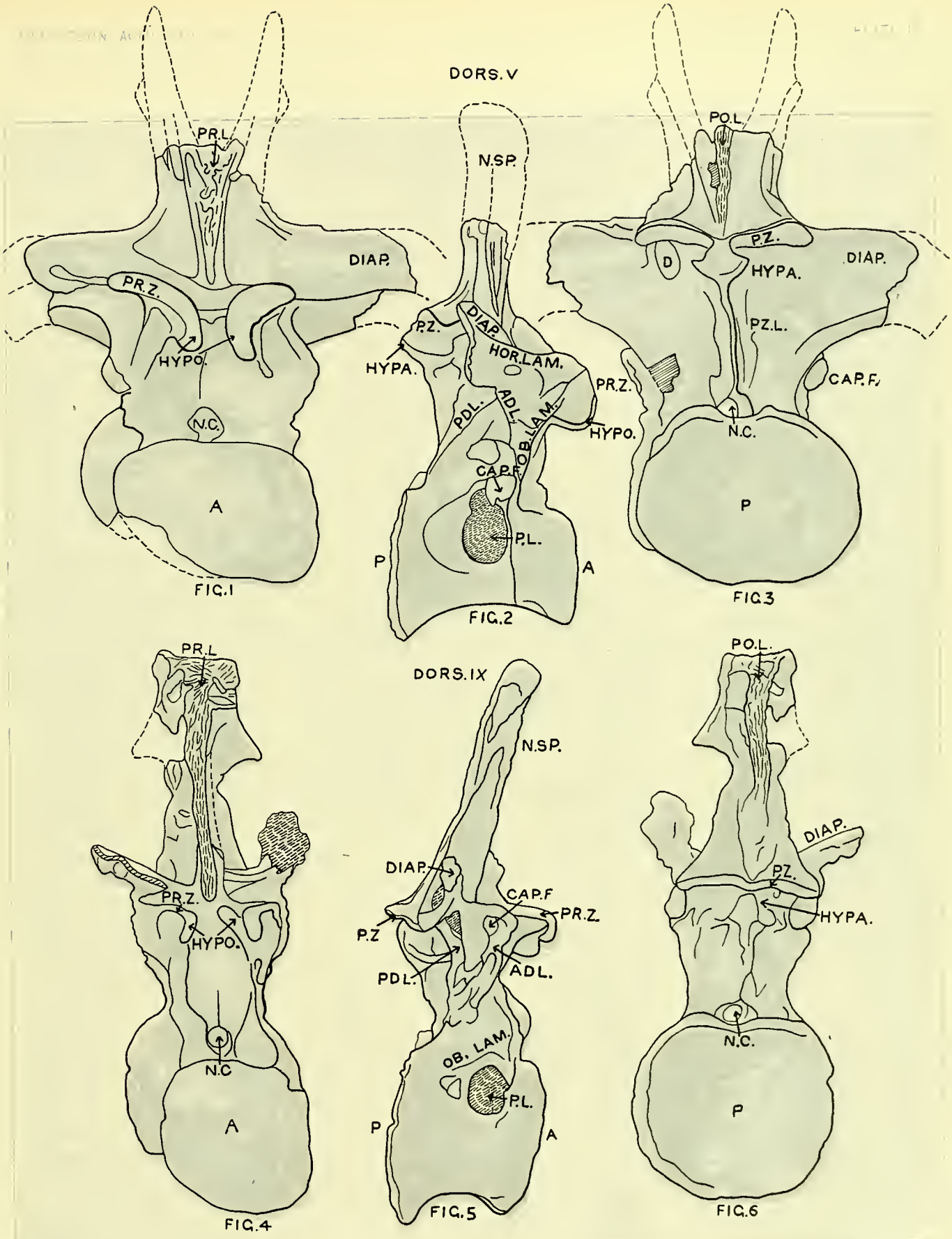
Figure 3. Dorsal V (Vertebra L), posterior aspect.

Figure 4. Dorsal IX (Vertebra N), anterior aspect.

Figure 5. Dorsal IX (Vertebra N), right lateral aspect.

Figure 6. Dorsal IX (Vertebra N), posterior aspect.

Key drawing: A, anterior, P, posterior face of centrum. ADL., anterior diapophysial lamina; D., depression; HYPO., hyposphene; OB.LAM., oblique lamina; PDL., posterior diapophysial lamina; PZ.L., postzygapophysial lamina; other lettering as in Plate III.


DORS. V
PR.L.
N.SP.
PO.L.
DIAP.
PR.Z.
HYPO.
N.C.
A
FIG.1
P.Z.
HYPA.
HOR.LAM.
PDL.
ADL.
OB.LAM.
CAP.F.
P.L.
P
A
FIG.2
D
P.Z.
HYPA.
DIAP.
PZ.L.
CAP.F.
N.C.
P
FIG.3
PR.L.
DORS. IX
N.SP.
DIAP.
PR.Z.
HYPO.
N.C
A
FIG.4
CAP.F
P.Z
PDL.
ADL.
OB. LAM.
P.L.
P
A
FIG.5
PO.L.
DIAP.
P.Z.
HYPA.
N.C.
P
FIG.6

DORS.V
N.SP.
PR.L.
DIAP.
PR.Z.
HYPO.
N.C.
A
FIG.1
PO.L.
DIAP.
HYPA.
PZ.
D
PZ.L.
CAP.F.
N.C.
P
FIG.3
DIAP.
PZ.
HOR.LAM.
HYPA.
PR.Z.
ADL.
PDL.
HYPO.
OB.LAM.
CAP.F.
PL.
A
P
FIG.2
DORS.IX
N.SP.
DIAP.
CAP.F.
PZ
PR.Z.
ADL.
PDL.
OB. LAM.
PL.
A
P
FIG.5
PO.L.
DIAP.
PZ.
HYPA.
N.C.
P
FIG.6
PR.L.
PR.Z.
HYPO.
N.C.
A
FIG.4

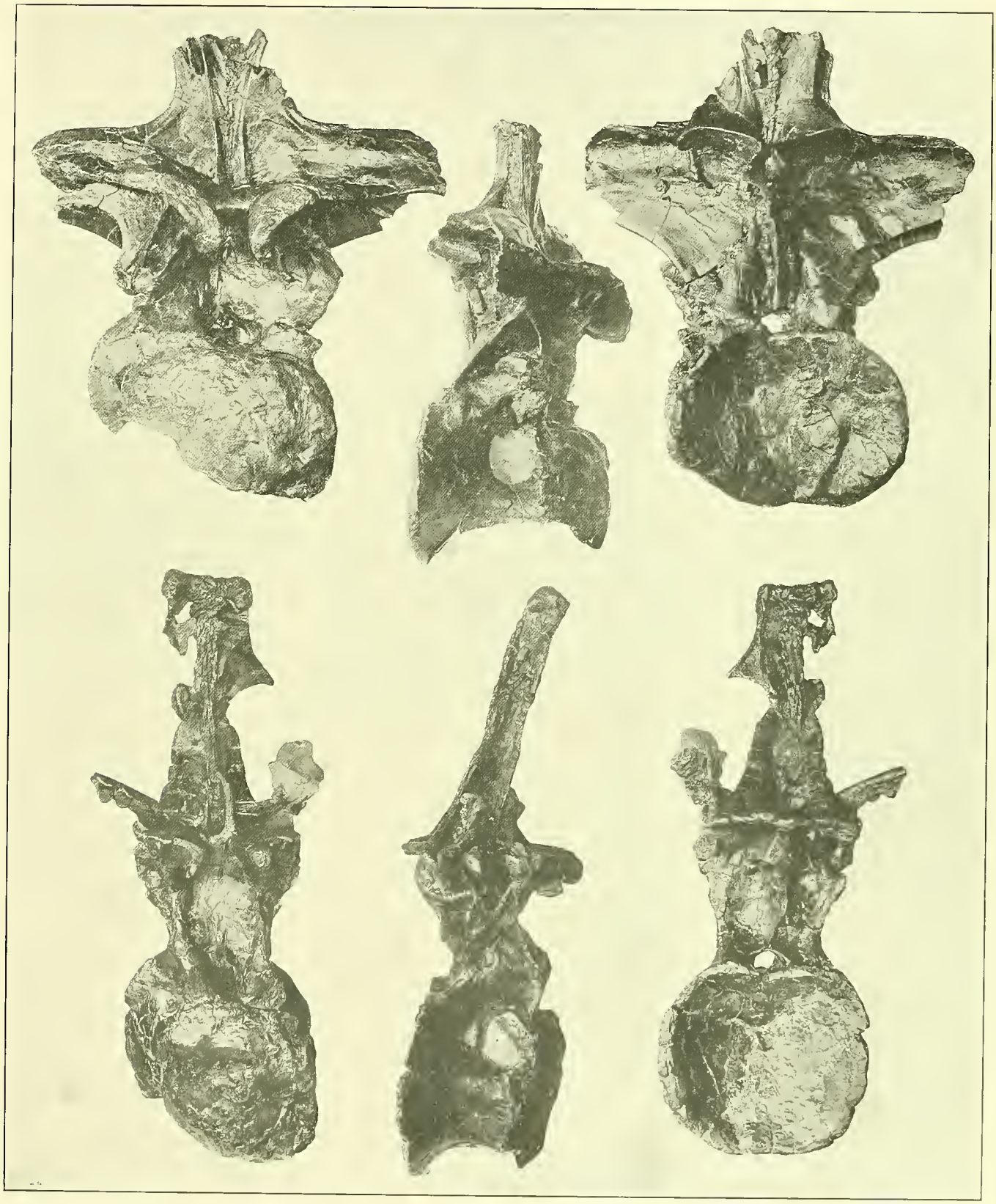


PLATE V. Caudal vertebræ of *Barosaurus*. About one-eighth natural size.

Figure 1. Caudal III (Vertebra K), anterior aspect.

Figure 2. Caudal III (Vertebra K), right lateral aspect.

Figure 3. Caudal III (Vertebra K), posterior aspect.

Figure 4. Caudal XV, left lateral aspect.

Figure 5. Caudal XV, anterior aspect.

Figure 6. Caudal XVII, left lateral aspect.

Key drawing: A, anterior, P, posterior face of centrum. DIAP., diapophysis; D.L., diapophysial lamina; N.C., neural canal; N.SP., neural spine; PO.Z., postzygapophysis; P.L., pleurocœle; PO.L., postspinal lamina; PR.L., prespinal lamina; PR.Z., prezygapophysis; PR.Z.L., prezygapophysial lamina.

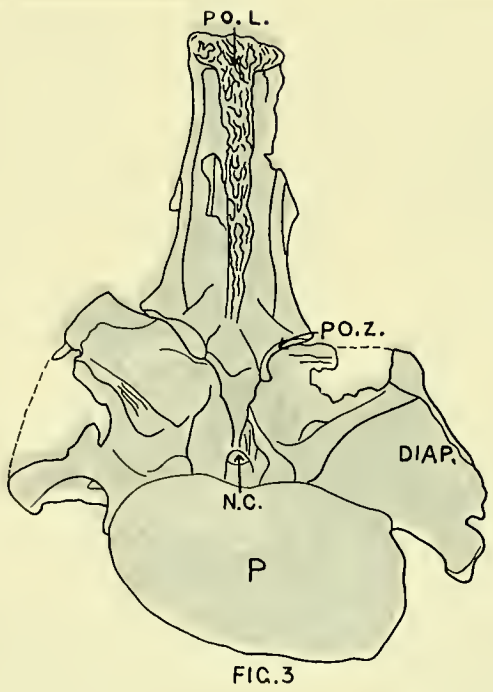


FIG. 3

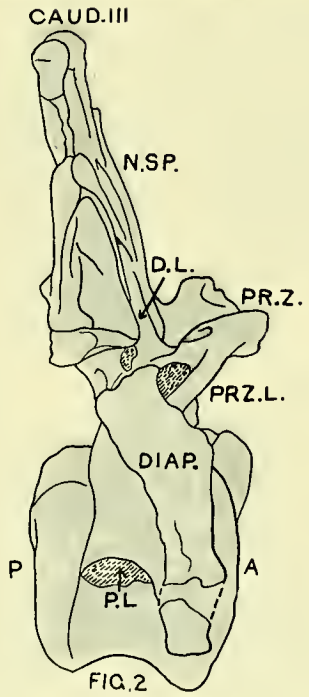


FIG. 2

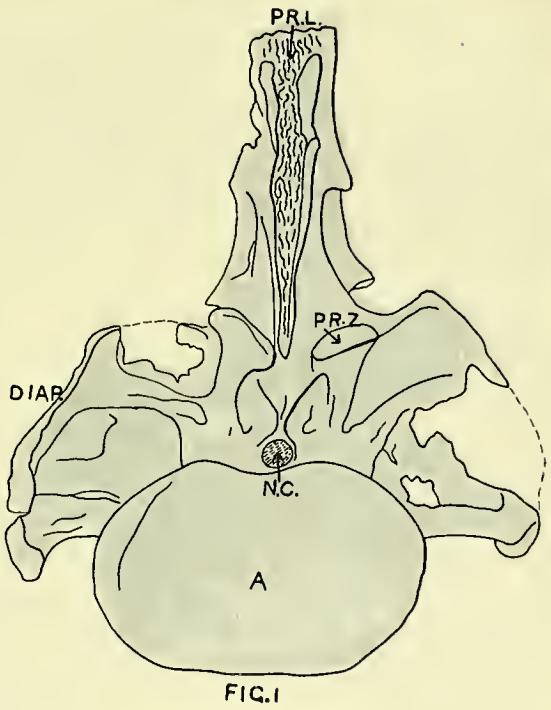


FIG. 1

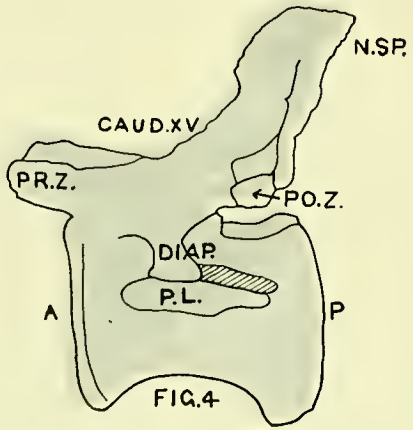


FIG. 4

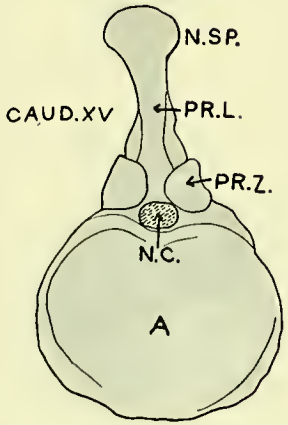


FIG. 5

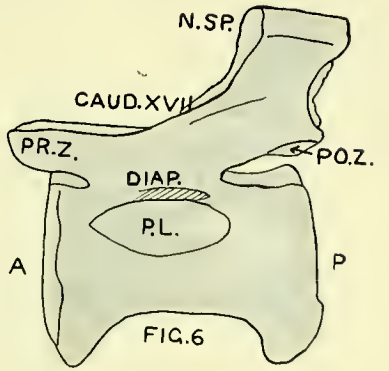


FIG. 6

FIG. 1

FIG. 2

FIG. 3

FIG. 4

FIG. 5

FIG. 6

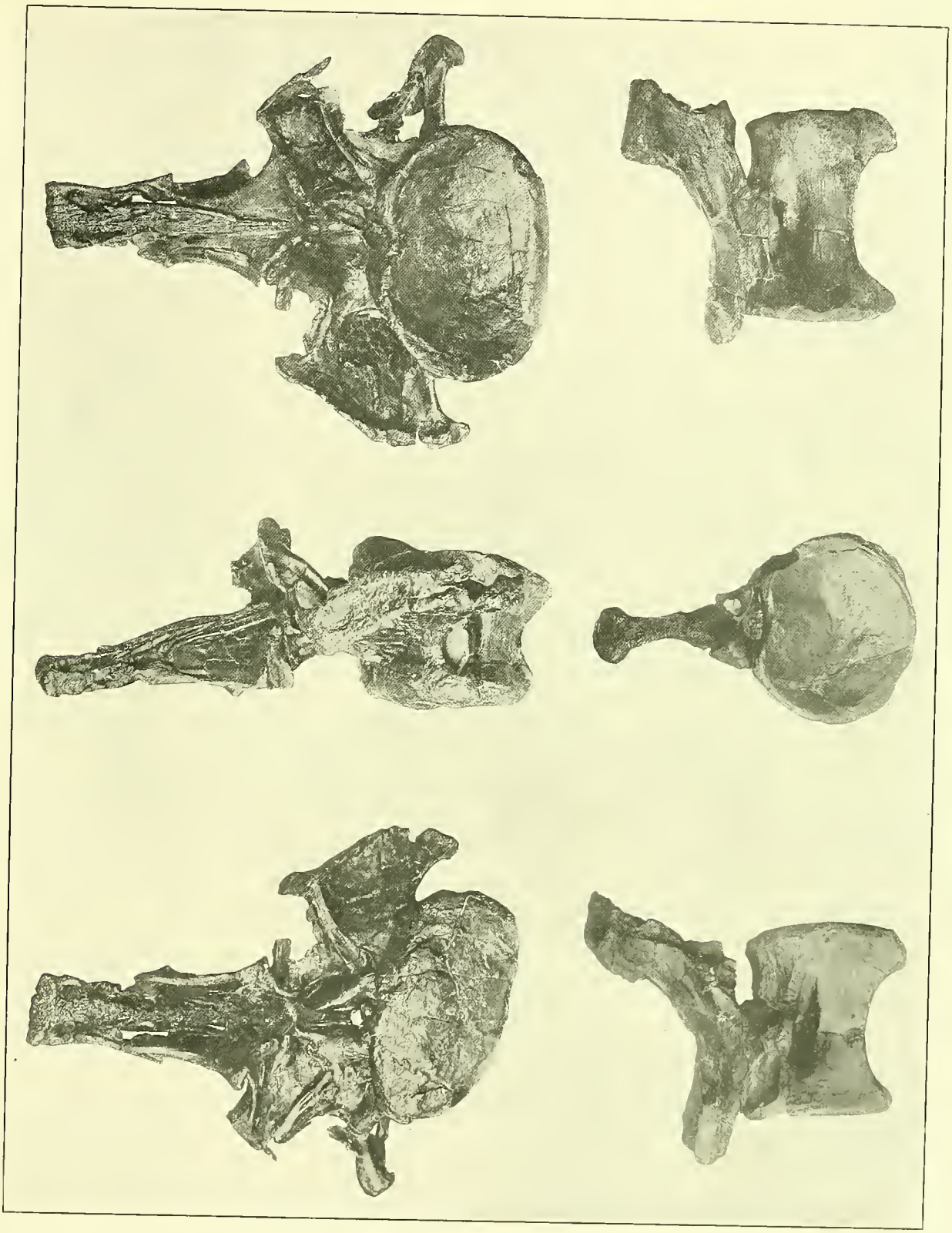


PLATE VI.

Figure 1. Sternal of *Barosaurus,* outer aspect. One-fourth natural size.

Figure 2. Pubis of *Barosaurus.* One-eighth natural size.

Figure 3. Summit of neural spine, dorsal VI, anterior aspect. About one-sixth natural size.

Figure 4. Caudal ca. XXXII. One-sixth natural size.

Figure 5. Chevron ca. V, right lateral aspect. About one-sixth natural size.

Figure 6. Chevron ca. IX, right lateral aspect. About one-sixth natural size. f, facet.

Figure 7. Chevron ca. XVI, right lateral aspect. About one-sixth natural size.

Figure 8. Chevron of *Diplodocus longus* type, right lateral aspect. About one-eighth natural size.

Figures 9-10. Metacarpals of *Barosaurus affinis* type. About one-sixth natural size.

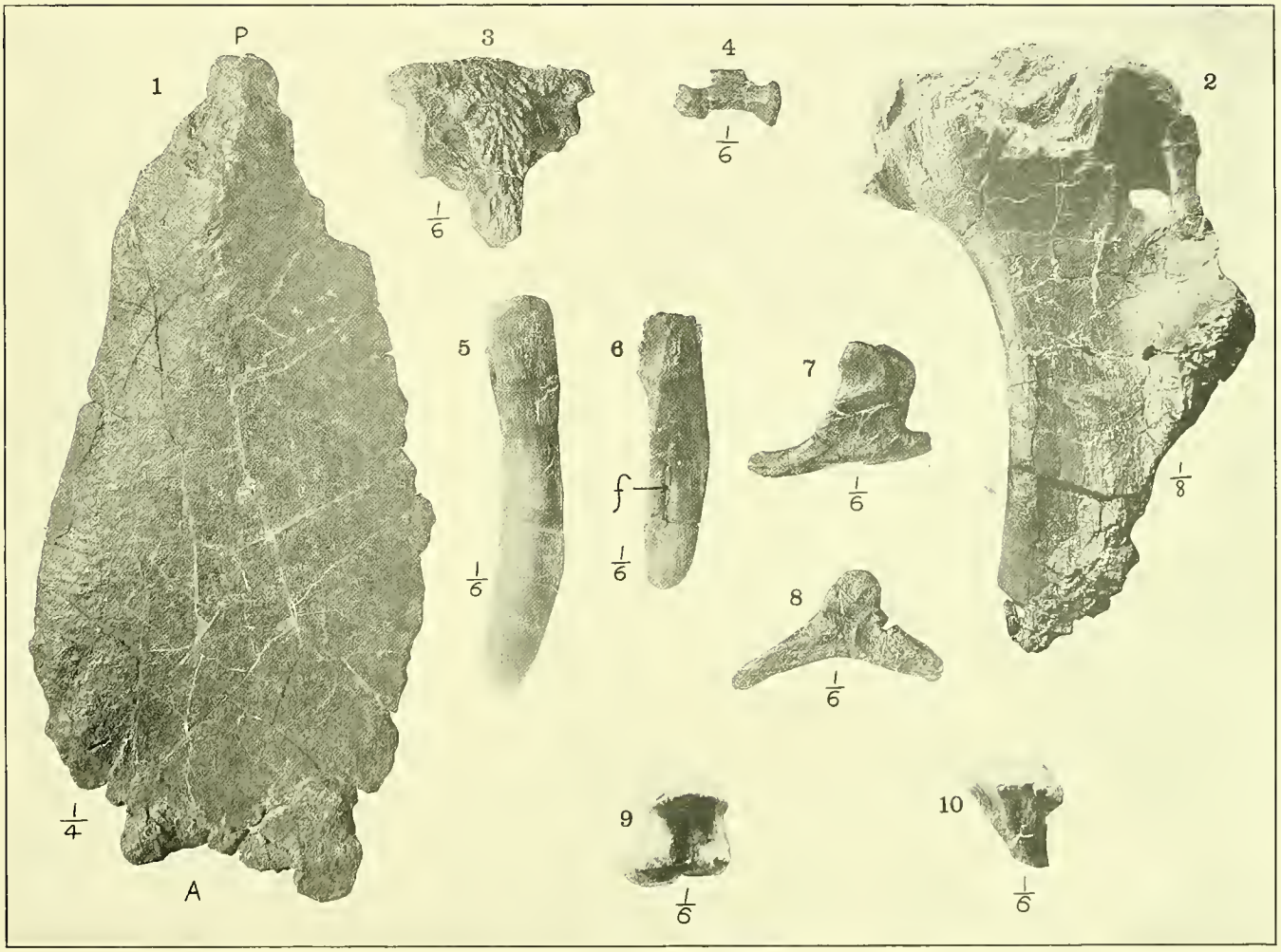
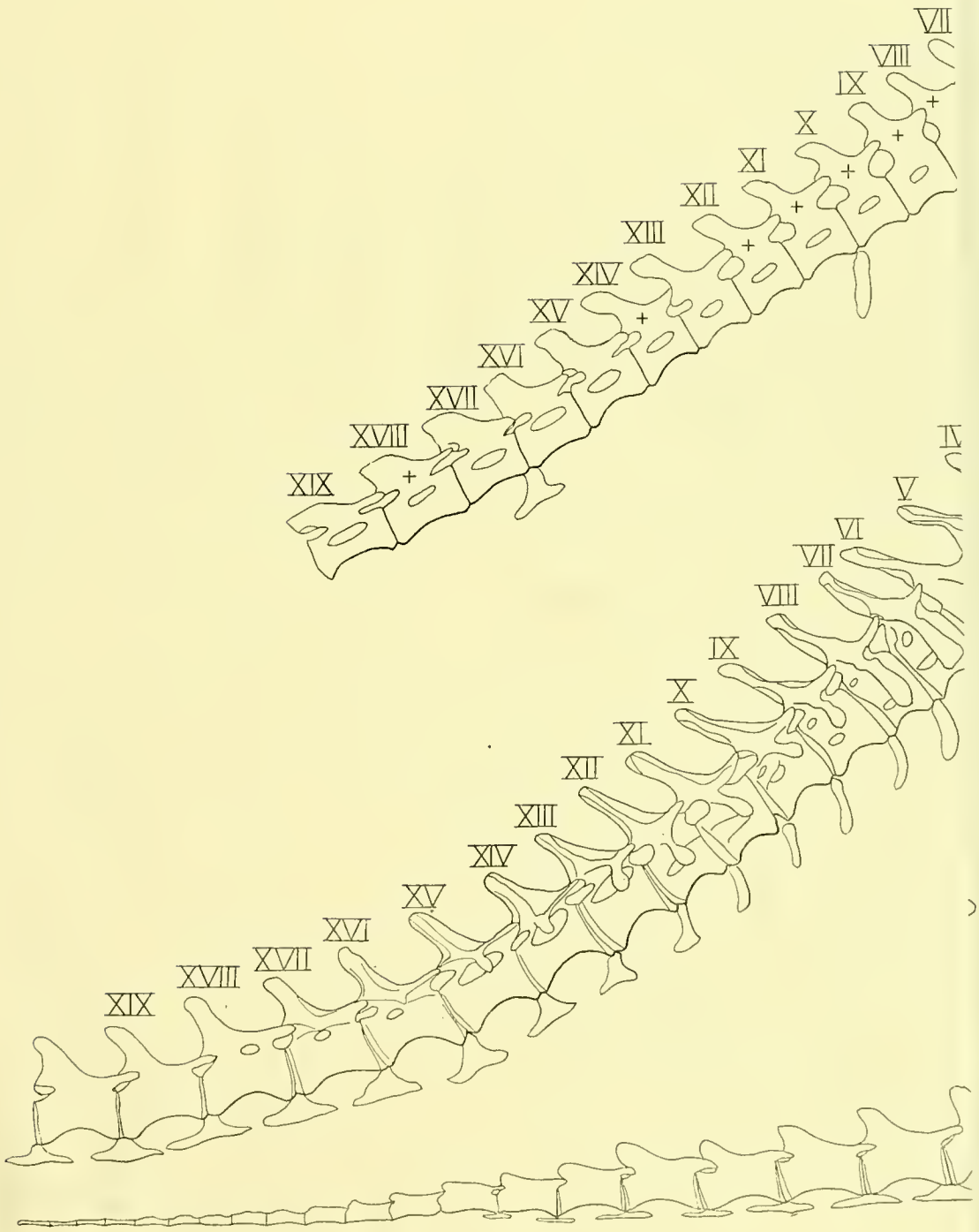

P
1
1/4
A
3
1/6
4
1/6
2
1/8
5
1/6
6
f
1/6
7
1/6
8
1/6
9
1/6
10
1/6

PLATE VII. Vertebral column of *Barosaurus lentus* compared with that of *Diplodocus carnegiei,* the latter after Hatcher 1901, Plate XIII. About one twenty-fifth natural size. The scapula of *Barosaurus* is slightly in advance of that of *Diplodocus.* The dorsal series of *Barosaurus* is slightly longer, the caudals much shorter, and with lower spines, while the four cervicals preserved are nearly equivalent in length to six of the posterior neck bones of *Diplodocus.* Of the femur, pubis, and ischium of *Barosaurus,* the portions preserved are indicated with their much greater relative bulk. Of the ilium, but the pubic peduncle and portions of the rim are recognizable; its size and shape therefore are conjectural. The preserved portion of the right scapula is indicated. No single rib is preserved in its entire length, so the volume of the torso could not be estimated. It is probable that the neck may have had an upward flexure, especially between cervical XV and the first dorsal and between the first and second dorsals, as its habitual posture. This is not, however, indicated as it would make the relative comparison with *Diplodocus* less emphatic.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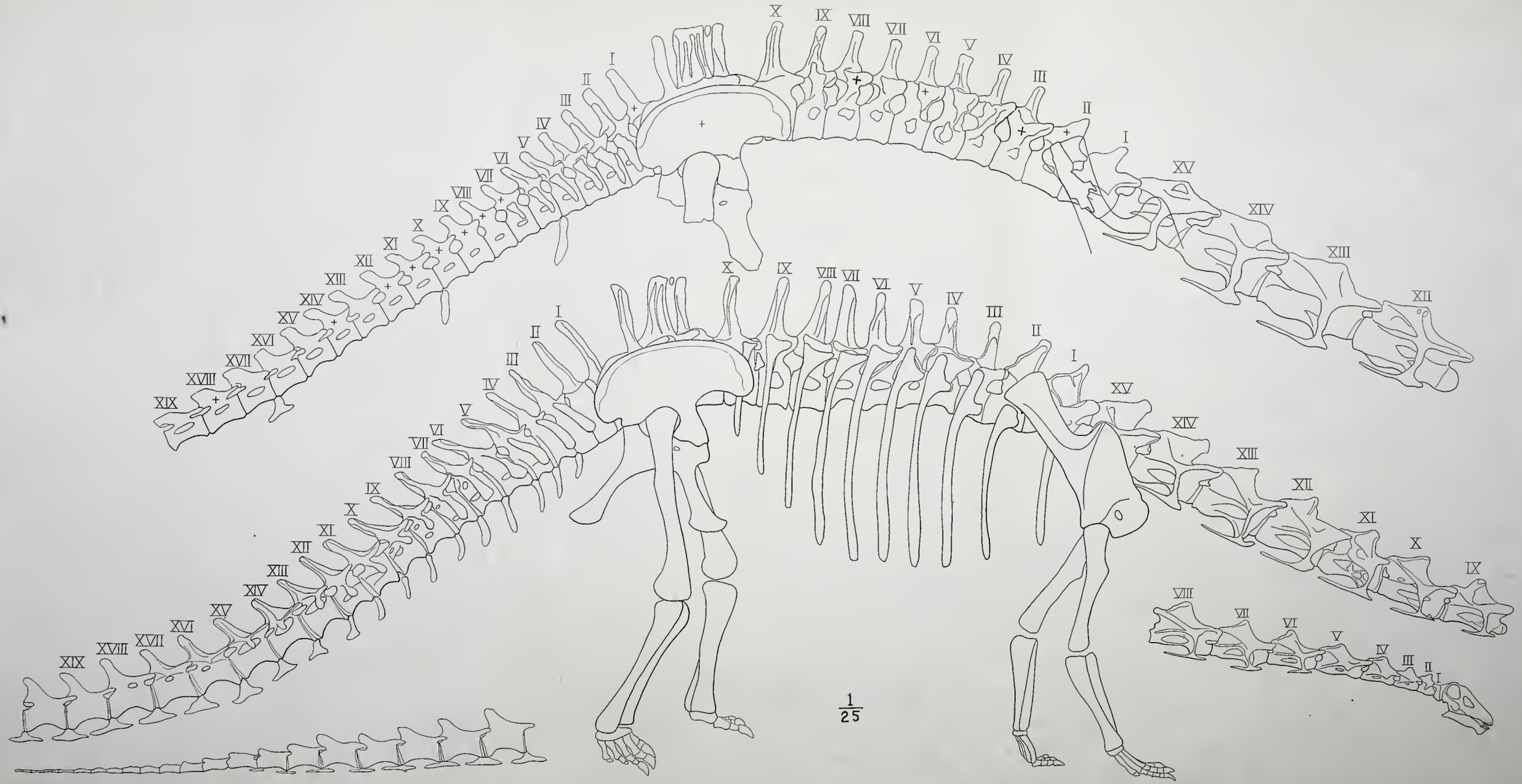
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